UNIVERSITAT ROVIRA I VIRGILI

INVESTIGATING THE MIDDLE TO UPPER PALEOLITHIC TRANSITION FROM THE SITES IN KHORRAMABAD VALLEY; WESTERN IRAN: WITH SPECIAL REFERENCE TO KALDAR CAVE

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Title: **Investigating the Middle to Upper Paleolithic Transition from the Sites in Khorramabad Valley; Western Iran: with Special Reference to Kaldar Cave**

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Dedicated to my beloved father and mother (Bakhshali Bazgir & Khadije Niazi) for going through tolerance of inexplicable pains and discomforts to shape me where I stand now

I acknowledge that this study entitled "Investigating the Middle to Upper Paleolithic Transition from the Sites in Khorramabad Valley; Western Iran: with Special Reference to Kaldar Cave" presented by Behrouz Bazgir to achieve a doctoral degree, has been supervised by me in the Institut Català de Paleoecologia Humana i Evolució Social (IPHES) and Department of History and History of Art of the University of Rovira i Virgili (URV). Hereby I state that this research work fulfils the requirements for the International distinction.

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Supervisor of the thesis
Dr. Andreu Ollé

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Abstract

This PhD thesis deals with a goal-oriented research towards understanding the transition from Middle to Upper Paleolithic in the Zagrous Mountains and its implications in global debates on this regard. This research is the results of a comprehensive field works carried out in four Paleolithic sites located in the Khorramabad Valley in the western part of Iran. Field works were carried out in two different excavation seasons in 2010-11 and 2014-15. In the first season, we excavated Gilvaran, Ghamari and Kaldar caves and Gar Arjeneh rock shelter. Except for Gar Arjeneh rock shelter that showed up a badly disturbed stratigraphy, excavations at the other three caves yielded positive results showing that all the caves were occupied from the Middle and Upper Paleolithic onward, and therefore provide great potential for the study of the transition between these two crucial cultural periods in this part fo the world. Our preliminary field observations and initial results of the analysis of the lithic assemblages showed that among all the excavated sites Kaldar Cave provides a better stratigraphic sequence with clear living floors that provides the opportunities for an accurate recognition of Middle and Upper Paleolithic layers. As a result, in 2014-15, we excavated the fill of Kaldar Cave in a larger scale that led to the discovery of cultural remains generally associated with anatomically modern humans (AMHs) as well as evidence of a probable Neanderthalmade industry in the basal layers. In the 2014-15 excavation we achieved four thermoluminescence (TL) dates for Layer 4, ranging from 23,100 ± 3300 to 29,400 ± 2300 BP, and three AMS radiocarbon dates from charcoal samples belonging to the lower part of the same layer, yielding ages of 38,650–36,750 cal BP, 44,200–42,350 cal BP, and 54,400–46,050 cal BP (all at the 95.4% confidence level). Although we have not yet achieved chronometric dates from Gilvaran and Ghamari caves, however, as rare cases these localities are also very important sites in the Zagros Mountains which are showing both Middle and Upper Paleolithic sequences. As a consequence, with the available data, Kaldar Cave is the first well-stratified Late Palaeolithic locality to be excavated in the Zagros which is one of the earliest sites with cultural materials attributed to early AMHs in western Asia. It also offers an opportunity to study the technological differences between the Mousterian and the first Upper Palaeolithic lithic technologies as well as the human behaviour in the region. The achieved dates highlights the region as one of the most important zone for the likely second wave of migratory groups of modern human out of Africa that succeeded

to dispers into Europe. This also cast more doubts on the singular role of Levantine for the modern human dispersal into Europe. In this thesis, I present the uptonow results from both the excavation seasons which includes detailed description of each site stratigraphy, quantified results from the lithic assemblages, preliminary faunal remains analyses, taphonomic aspects, interpretation of the regional paleoenvironment and geochronologic data from Kaldar Cave. Apart from the published results presented here in this thesis (Bazgir et al. 2014, Davoudi et al. 2015, Bazgir et al. 2017 and Becerra-Valdivia et al. 2017), I provided more details from our excavations as well as some of our multidisciplinary analysis carried out on techno-typological and functional analysis on the lithic industries as well as anthrachological analysis on the recovered charcoals from Gilvaran and Kaldar caves. With the mentioned achieved results that came from efforts by several specialists from different universities and institutes participants, I believe that we succeeded to build aglobal position for the study area and a project for future studies aboutthe human evolution in this region and beyond.

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Chapter 1: Introduction

In this chapter, I discussed how this thesis has been built by providing a brief history of the conducted major studies within the Iranian Zagros, a general discussion on the research problems, aims and questions, hypothesis and the field exploration. According to the current state of research of the subject in the selected area, my main contribution consisted in contributing original archaeological information, investigated from an interdisciplinary approach that reached to production of impact papers which build a consistent research project.

In chapter 2, the provided information deal with geographic setting of the Lorestan province as a whole, current environmental condition of Khorramabad and its geographic and water resources and finally general information on geology of Iranian Zagros, Khorramabad region and Kaldar Cave perimeter.

Chapter 3 presents the archaeological works and results of the excavations conducted at Gilvaran, Ghamari and Kaldar caves and Gar Arjeneh rock shelter. Additionally, detailed information such as stratigraphy and archaeological context, lithic industry, faunal remains and analysis carried out on each site assemblages have been discussed.

In chapter 4, a detailed study of Kaldar Cave Middle and Upper Paleolithic assemblages have been presented.

Chapter 5 deals with a general discussion on Middle to Upper Paleolithic transition within Iranian Zagros and its role as one of the regions that might had an important role for the dispersal of modern humans into Europe. Here, there have been also discussion on arguments between researchers who worked/working on Iranian Zagros sites and provided some information about the key sites of the region and their role in debates. Additionally, in the conclusion section, the most important results of the conducted excavations have been discussed and finally the future of this research has been discussed as a sub-chapter “research perpectives”

All the published papers have been included between the text according to their appropriate position within the chapters.

1-1: A brief history of the major Paleolithic studies in Iranian Zagros Mountains

During the 1930s, Henry Field reported Upper Paleolithic type of lithics at two rock shelters in the Fars province, on the shore of Maharlu Lake near Shiraz (Field, 1939, p. 495). He was also the first person who recognized the archaeological importance of Kunji cave at the outskirt of Khorramabad city in Luristan province in central Zagros (Field 1951: 91, footnote 22).

From June to November 1949, Carlton S. Coon, explored four localities, out of which two of them were from Zagros. Hunter´s cave of Bisitun Mountain in Kermanshah province in southwestern Iran and Tamtama Cave overlooking Urmiya Lake in Iranian Azerbaijan. He excavated these sites and assigned them to Middle and Upper Paleolithic (Coon 1951and 1957). In 1959, Bruce Howe excavated Kobeh Cave in the Kermanshah province in Western Iran yeilding Middle Paleolithic assemblage. In the beginning of 1960, the important site of Warwasi rock shelter was also excavated by Bruce Howe under direction of Robert Braidwood. This site contains a rich archaeological sequence from Middle Paleolithic to late Epipaleolithic.Braidwood also reported Lower Paleolithic artifacts from Gakia in Kermanhah province (Braidwood 1960,Braidwood et al. 1961). Since then, Braidwood´s students (Frank Hole and Kent Flannery) continued this mission in the Luristan province. Their main focus was the Khorramabad Valley where numerous caves and rock shelters exist. They excavated five localities (Ghamari, Kunji, Yafteh caves) and (Gar Arjeneh and Pa Sangar rock shelters) (Hole and Flannery 1967). It was in 1969, when McBurney tested three rock shelters in Kuhdasht region near to Khorramabad sites in Luristan province. He excavated Humian 1 & 2, and Barde-Spid). Among them Humian1 showed Mousterian assemblages (McBurney 1969,1970). This site is one of the most important localities not only in Luristan province but in the country, holding the oldest archaeological layer in Iran. The Mousterian occupation in Humian 1 suggests the Th/U dates of 148,000±35,000 BP (Bewley 1980, 1984: 35-38). These dates define and connects Humian1 with the Middle Paleolithic chronologies of the Near East (Mercier and Valladas 1994).

During the “cave exploration” Project in Iran, Ghar-e-Khar was reported by Carleton S. Coon in 1949 and then it was in 1965, when Philip E.L. Smith and T. Cuyler Young as a part of prehistoric survey from Kermanshah to Azerbaijan in the north of Iranian Zagros, selected this site for excavation. Withouth reaching to bed rock, the site revealed a sequence beginning from the Late Middle Paleolithic to the Epipaleolithic onwards, comparable to those from Shanidar Cave (Young and Smith; 1966, Smith, 1986).

After the small test excavation in the Kunji Cave by Henry Field in 1951, and the excavation by Hole and Flannery, it was in 1969, when a large scale excavation at this site was conducted by John D. Speth (Speth1971). Later along with Mark F. Baumler, he published a detailed techno-typological analysis of the recovred Mousterian assembalges in this cave. (Baumler and Speth, 1993).

In 1974, Marcello Piperno visited the area near Maharlu Lake and studied some artifacts in the region that had already been visited and mentioned by Henry Field in the Fars province in central Iran (Field, 1939). Based on typology he assigned the Eshgaft e Ghadi Barmishur´s assemblage to the Middle Paleolithic period (Piperno,1974). An archaeological survey by Peder Mortensen in 1973, aimed to recostruct the settlement patterns of prehistoric era in the Hulleilan Valley in Luristan. In his field mision he reported twenty four localities chronologically ranging from Lower to the Epipaleolithic times. (Mortensen 1974a, 1974b, 1975, 1993).
In 1976, three caves and seven Paleolithic opensites were reported by Sadek-Kooros from Maragheh región in northwestern Iran in Azerbaijan área. Sheassigned them to the Lower Paleolithic. Due to lack of proper technological documentations at that time, up to now, exact location of these sites remained unknown (Sadek-Kooros, 1976).
In 1969, during his survey in Kur River Basin, William Sumner brought to attention the Eshkaft-e Gavi cave (Sumner 1972). Since then, it was in 1978, when Michael Rosenberg conducted a sondage at Eshkaft-e- Gavi (Rosenberg, 1985) and reported the presence of a continous sequence from Middle to Epipaleolithic times in this site (Rosenberg, 1988).

A mission from Kyoto University led to documentation of several Paleolithic sites in the Arsanjan área in the southern Zagros, but except for some illustrations of the lithics, no more description is available on their finds. (Ikeda 1979; Tsuneki and Nishida 2007).

In 1984, Harold Dibble restudied the Mousterian assemblages of the Hunter Cave in Bisitun which were recovered during the 1949 expedition by Coon (Coon, 1951) , and claimed that Bisitun collections demonstrate relatively high quantity of Levallois technique. Furthermore, he also established a model for scraper reduction based on the Mousterian materials from the Zagros Mountains (Dibble, 1984).

It was in 1993, when Deborah Olszewski started an extensive research on Paleolithic assemblages on Zagros materials. More specifically, on Warwai rock shelter which was excavated by Howe. She is the first person who proposed the term “Zagros Aurignacian” for the Early Upper Paleolithic assemblages of the Zagros and was supported later by Dibble. (Olszewski, 1993; Olszewski & Dibble, 2006).

John Lindly´s comparision anlaysis on Middle Paleolithic assemblages between the sites in highland of Zagros with those from the lowland suggested a seaonal settlements in Zagros (Lindly, 1997). In his model, he proposes a migratory model that, during the Pleistocene time, Paleolithic societies had no other option except for migrating from the highlands to lowland areas in the nearby Central Iranian Desert and Khuzestan Plain (Lindly, 2005).

In 1999, among the sites that had ben already reported and excavated by Hole and Flannery in1963 mission (Hole & Flannery, 1967), in an extensive field survey conducted by Roustaei and colleagues, 21 Paleolithic sites have been reported from the Khorramabad Valley and it´s nearby regions such as Kuhdasht and Pol-e- Dokhtar (Roustaei et al., 2002, 2004).

Between 1999 and 2001, a survey by three Iranian archaeologists in Islamabad plain in the Kermanhah province in western Iran (Abdi, 1999, Abdi et al., 2002) led to discovery of some Paleolithic sites among them Wazmeh cave and the open site of Amarmerdeg (Lower Paleolithic) were the major ones. Simultaneously, Wezmeh cave was tested by a small excavation and discovery of a human Maxillary premolar dated to the Upper Paleolithic (Trinkaus et al., 2007).

A survey on Bisotun Cave in the Kermanshah región conducted by Biglari, showed some Paleolithic finds from this locality. (Biglari 2001). At the same year, Biglari and Heydari reported a surface Mousterian assemblage from Do-Ashkaft Cave (Biglari and Heydari 2001).

In 2004, a study of raw material and usage of the Middle Paleolithic occupation with special reference to Do-Ashkaft Cave located in the Kermanshah plain was conducted by Biglari and argued that the better quality non-local flints were used for production of blanks used in formal tools. (Biglari 2004).

In the same year, Biglari and Ghafari reported some Middle Paleolithic artifacts near Maragheh, in the southeast of the Urmieh Lake (Biglari and Ghafari 2004).

As a result of a surface collection by Biglari in 2000, in 2004, Mar-Tarik, a Middle Paleolithic cave was excavated by a joint Iranian-French team (Jaubert et al., 2009).

In 2004, as a research Project, a joint Iranian-German team so called “the Tübingen-Iranian Stone Age Research Project” (TISARP) reported numerous Paleolithic localities from the southern foothills of Zagros and northern Khuzistan in the Basht region, among them there were several Upper and Middle Paleolithic sites mostly in the form of caves and rock shelters (Conard et al., 2009, Ghasidian et al., 2009).

In 2005, a joint project between the centre for Paleolithic research in the National Museum of Iran and the University of Liège, led to excavation of Yafteh Cave, which was a reevaluation of the excavation conducted by Hole and Flannery in 1960´s (Hole & Flannery, 1967) in this site (Otte et al. 2007). This new excavation Project by Otte and Biglari in 2005, and then Otte and Shidrang in 2008, aimed to obtain new chronometic data to test the potential the site for the posible transition from Middle to Upper Paleolithic (Otte et al. 2007). In their excavation report, they claim that there is a probable intermediate chronological position of the Baradostian or Zagros Aurignacian in south west Asian Early Upper Paleolithic sequence and suggesting overlapping with the Ahmarian and pre-date most of the dates of Levantine Aurignacian (Otte et al. 2011).
The earlier dates from Yafteh suggested an age between 24,500 and 36,000 14C BP. But the more recent results showed the date approximately 33,500 14 C BP for the major part of the sequence. However, the oldest Upper Paleolithic occupations in Yafteh were dated to 35450±600 BP (Otte et al., 2007).
One of the most intensive survey in the southern Zagros was carried out by a joint Iranian-German team so called as Tubingen Iranian Stone Age Research Project (TISARP) in the Dasht-e Rostam-Basht región that led to discovery of numerous Paleolithic localities in the área; one of which (Ghar-e-Boof) has been excavated and dated back to 40,000 cal BP for it´s early phases of Upper Paleolithic and claimed as one of the oldest Upper Paleolithic sites of Iran (Conard et al. 2006, 2007;Ghasidian et al. 2009, Ghasidian 2010, Heydari-Guran 2010,Conard and Ghasidian 2011).

A Paleolithic survey was conducted at the northern shore of Parishan Lake located in the southernpart of Fars province in south-central Iran. The lithic assemblage from a cave complex so called “Helak cave complex”, suggests the area was occupied by the end ofUpper Paleolithic period (Vahdati Nasab et al., 2008).

Another Paleolithic survey was conducted in Izeh Plain located in the southern part of Zagros that led to discovery of several caves and rock shelters in this region which were showing occupational patterns during the Epipaleolithic and begining of the Holocene (Niknami et al., 2009).

In 2009, a survey by Roustaei in the Bakhtiari region located in the south-central Zagros Mountains, led to identification of numerous localities mostly associated with lithic industries attributed to Middle Paleolithic in the highest altitude reported ever (Roustaei 2010).

In the same year, results of a recent study on Eshkaft-e Gavi (Scott and Marean, 2009) was published. The site was discovered by W. Sumner in 1969 during a survey, and M. Rosenberg investigated it in 1978. The site was excavated as a part of Malyan Project, directed by W. Sumner and R. Dyson (Rosenberg, 1985) that provided several fragments of hominin remains. The Eshkaft-e Gavi cave contains Middle Paleolithic and Upper Paleolithic deposits with some Epi- Paleolithic remains which all of the hominin remains come from the Upper Paleolithic and Epi- Paleolithic deposits. In their study, they state that the hominin remains represent anatomically modern humans but they also mention that the age of the bulk of the sample is uncertain. A molar recovered at the base of the Upper Paleolithic sequence near the boundary with the Middle Paleolithic. According to Scott and Marean, this molar lacks diagnostic Neanderthal features and is morphologically similar to modern human material. Despite the substantial disturbance had occurred from mechanical excavation of the talus slope and partial collapse of the roof from blasting (Scott and Marean 2009), this molar has very important implications for Early Upper Paleolithic of Zagors, indicating that the Baradostian appears to be associated with modern humans similar to the early Upper Paleolithic industries in Europe. In their reprot, they also argue a probability of canninalism activity in the site relying on four hominin specimens that have shown clear traces of stone-tool butchery by humans.The Eshkaft-e Gavi hominin sample expanded the record of human butchery of human carcasses into the Upper Paleolithic or Epi-Paleolithic of the Zagros Mountains (Scott and Marean, 2009).

In 2010, a survey by Moradi and Bakhtiari let to discovery of several Paleolithic sites, some of them encompassing surface materials of Upper Paleolithic elements in the Kuhdasht region of Luristan province (Moradi&Bakhtiari 2010).
In the same year, (2010), a survey conducted by Darabi and collegues in the Mehran Plain of Illam province led to discovery of 15 Paleolithic sites, chronologically ranging from Lower Paleolithic to Upper Palelithic and onwards (Darabi et al 2012).

It was again in the same year (2010), when one of the largest regional studies and goal-oriented Paleolithic research initiated under the directorship of the author (Bazgir). The achivements up to now and the aims of this research will be discussed in the following chapters in this thesis.

In 2011, a new chronological data provided from Yafteh sequence pointed to a probable intermediate chronological position of the Baradostian or Zagros Aurignacian in south west Asian Early Upper Paleolithic sequence, argued to overlap with the Ahmarian and pre-date most of the dates of Levantine Aurignacian. In their report, they claim that, the dates suggest the attribution of the sequence to an age between 24,500 and 36,000 14C BP. However, the more recent results indicate a single chronological signal of approximately 33,500 14 C BP for the major part of Yafteh sequence (Otte et al. 2011).

Nearly after five decades from the excavtion at Yafteh by Frank Hole and Kent Flannery in 1970´s, Hole published their excavation in an elaborated report in a book by Otte, Shidrang and Flas (Hole 2012). In the same year, results of the faunal remains of Yafteh Cave was published (Mashkour et al. 2012).

In 2013, one of the major studies on the aspect of emergence of the Aurignacian which was seeking evidences of in situ evolution of the Upper Paleolithic from a local Mousterian in the Zagros Mountains was performed by Tsanova. She tested her hypothesis by way of a taphonomic, technotypological and economic approach applied on two important sites of Yafteh Cave and Warwasi Rock shelter (Tsanova 2013). Although she found almost certainly the evolution in situe from Middle to Upper Paleolithic from Warwasi assemblage, however, Tsanova raised doubts concerning whether the Iranian Zagros could be argued to be the source of bladelet technology (Tsanova 2013).

A survey by Biglari and colleagues reported some scattered surface finds in the form of caves and rock shelters in Salas Babajani city in the Kermanshah province; out of which 2 sites (so called Salmaneh and Darband Zard) comprising Upper Paleolithic artifacts (Biglari et al. 2013).

In the same year (2013), the first results of the excavations at Gilvaran, Kaldar, Ghamari caves and Gar Arjeneh rock shelter was published (Bazgir 2013).

In continuation of this research program, with a joint Iranian-Spanish team, an elaborated report of the excavations at the Gilvaran, Kaldar, Ghamari caves and Gar Arjeneh rock shelter was published (Bazgir et al. 2014). Preliminary results showed that all of the sites were occupied from theMiddle and Upper Paleolithic onward, and therefore provide great potential for the study ofthe transition between these cultural periods.Our preliminary techno-typological observations also showed that the lower levels of the Gilvaran and Ghamari sequences may represent an early phase of the Middle Paleolithic, yet to be tested by chronometric studies (Bazgir et al. 2014). In addition to the excavation reports of these localities, a multidisciplinary palynological analysis studies including pollen and Non Pollen Palynomorphs from Gilvaran and Kaldar caves provided (although spores), but the first evidence of recovered Pliestocene pollens in stratigraphic context in Iran (Allué et al. forthcoming).

Subsequently, without any gap, we published in the same year, the preliminary results of some of our micro-wear and techno-functional analysis from Gilvaran, Ghamari and Kaldar caves (Bazgir and Tumung 2014). In the same year (2014), we also managed to publish our excavation results in the 12th Annual Symposium on Iranian Archaeology (Bazgir and Davoudi 2014). As a part of the multidisciplinary studies on the recovered materials from these localities, we began a series of residue analysis on the lithic industries. A preliminary report on the residues was published a poster in the XVII UISPP World conference in Burgos (Ollé et al. 2014).

In the same year (2014), Shidrang published a synthesis on Middle to Upper Paleolithic transitional industries from the assemblages of Middle East (Shidrang 2014).

At the end of 2014 (December) and beginning of 2015 (January and February), with a joint Iranian-Spanish team, we excavated Kaldar Cave for the second time but this time in a larger scale. Subsequently, the first dating results from Kaldar Cave was published as a poster in ESHE conference. The main aim of the project isestablishment of a reliable chronology in the Zagros Mountains to achieve a clear chronological definition of the M-UP transition for this region. It also aims to improve the situation, by focusingon the radiocarbon dating of organic materials extracted from several key Palaeolithic cave sites: such as Kobeh, Kaldar, Ghār-e Boof, and Shanidar (Iran & Iraqi Kurdistan), as well as the modelling of previously published radiocarbon determinations for the cave site of Yafteh Cave (Becerra-Valdivia et al 2016).

As mentioned above, we started this research project in 2010, aiming to understand the central Zagros chronology and it´s Paleolithic occupational periods and settlement patterns. As a part of this project, in 2014, in a survey by Davoudi and the author, we manage to discover a Lower Paleolithic locality in the Huleilan area of Luristan (Davoudi et al 2015). To know the details of this discovery, the entire article is presented here in the chapter 5 of this thesis.

As a part of his PhD thesis, Davoudi initiated his research line in the Huleilan region aiming to discover new sites and re-evaluate Mortensen´s works. As a part of this, he and colleagues reported some Middle Paleolithic sites that was previously claimed to be Upper and Epipaleolithic sites by Mortensen (Davoudi et al. 2015, Mortensen 1974a, 1974b, 1975, 1993).

In 2016, Shidrang and Biglari studied the lithic assemblage of the Ghar-e-Khar Cave. (Shidrang and Biglari 2016). In their study, they analyzed the Middle and Upper Paleolithic industries of this locality to test the hypothesis that weither there is any existence of continuity or local emergence from Mousterian to Baradostian in the Zagros Mountains. In their techno-typological analysis, they state that “However, from the current state of data, the paper concludes that our technological data supporting the hypothesis of Middle-to-Upper-Paleolithic continuity in Zagros are insufficient, and we can neither confirm nor reject the possibility of a gradual transition in this region” (Shidrang and Biglari 2016).

The first excavation report of the second season at Kaldar is published in the 14th Annual Symposium on Iranian Archaeology (Bazgir 2016). As a part of the multidisciplinary studies on the recovered materials from Kaldar, we also manage to present a posteron preliminary report on the Paleoenvironmental reconstruction of the area by the help of micro-faunal studies (Rey Rodríguez et al. 2016).

In 2017, a comprehensive chronometric and typo-technological study from the Ghar-e-Boof was carried out by Ghasidian and colleagues. In this work, authors correctly pointed out that,the Zagros Mountain range reflects multiple technological traditions instead of a single one (Ghasidian et al. 2017).

Finally, the newly excavated sequence in Kaldar Cave provided evidence for the replacement of the Mousterian industry, usually associated with Neanderthals, by the Baradostian industry, similar to the Aurignacian, which is unique to anatomically modern humans. Excavations at Kaldar Cave have yielded evidence for Baradostian (Layer 4) and Mousterian assemblages (Layer 5) in stratigraphic superposition. This is an exceptional find in the Zagros. We have obtained new chronometric data from the site. Four TL dates from the uppermost Layer 4 revealed ages that ranged from 23100 ± 3300 to 29400 ± 2300 BP. The three 14C dates from Layer 4 and sub-layers 5 and 5II produced results in the ranges of 38650–36750 cal BP, 44200–42350 cal BP, and 54400–46050 cal BP, respectively (all at 95.4% probability). The wide chronometric ranges and few dates do not allow us to make a confident and precise assessment of the age of the transition to the Upper Palaeolithic. Further work is needed to refine the chronology. In addition to the presence of a clear Mousterian industry in the > 0.5-m-thick Layer 5 and despite the need for more chronometric data, the obtained dates from the lower part of the Upper Palaeolithic sequence in Kaldar Cave are some of the earlier dates attributed to a lithic industry produced by AMHs in western Asia (Bazgir et al. 2017 and Becerra-Valdivia, et al 2017).

1-2: Statement of Problem

As every other archaeological investigations, it is obvious that the first step to deal with any kind of research, begins when a researcher face one or several problems along with hypothetical possibilities to resolve them in his mind. In the second thought, it comes the time to find a way to answerthe passive questions that were not dealt by others in the past or have not been given enough attention to their overall importance. As a consequence, any research aim, initiate to improve the relevant topic towards the facts to add a little more to the unknown parts of it. In some cases, in archaeological investigations, first problems appear while selection of a site or study area, not because of lack of archaeological sites, but due to otherfactors that could make it uncomfortable and complicated in several aspects. In many cases it could become an extremely complex issue and unconsciously can provide disproportionate negative impact on the quantity and quality of the research results.Therefore, prior tostarting any research work, evaluatingthe conditions of topic and study areais the must. Especially in the field of archaeology, where core of the studies built up on field work which in most of the cases more specifically in the long term projects (like the present research), requirement of physical presence and continuous accessto the study area or region is inevitable.For this principal reason, in order to avoid complications and to minimize the problems related to a long term research, the first step could be the easy access to the study area or the region. An easy access to the site / sites cannot be limited only to one or several excavation seasons, but in the majority of the cases, studying a site and it´s relevant materials requires a long time, in many cases years or decades. In order to better clarify the matter, among many flag sites around the world sites such as Sierra de Atapuerca has been studied nearly five decades since the first excavation season in 1964 (Carbonell et al. 2014). Another example in Spain is the Abric Romaní rock shelter, where it is under excavation and investigartion since 1990, nearly three decades (Vallverdú et al. 2014). It is believed that continuation of various studies and analysis on materials from the both Sierra de Atapuerca and Abric Romaní seems essential for the coming next decades.

Coming to the point, a quick observation into the published literature carried out byindependent foreign researchers clearly show the discontinuity and long time gaps of the works and consequently the results are limited to few preliminary and scattered reports. Author believes that one of the main reason for such lacks could be the limited access of the foreign researchers to the study area and the sites (personal conversation with Prof.Otte). Other important factor for such problem was a hiatus of more than 20 years due to Iran-Iraq war and political instability in the region. However, in contrast to such situation, the joint international researches organized by the Iranian archaeologists are showing much more fruitful and continuous results. In this case, for instancethe “Tübingen Iranian Stone Age Research Project (TISARP)” working on the southern Zagros, “French and Iranian Paleoanthropological ProGarm (FIPP)” focused on Alborz Moutains, “Joint Iranian - Belgian team” worked mostly on Yafteh Cave, and finally the current “Khorramabad Project” by our Iranian-Spanish team including several more experts from different universities and institutes, are the best examples for this argument.Neverthless,being aware of such issues and taking into account the richness of the Paleolithic potentiality of the Khorramabad Valley, I put the first step forward as a native residence and initiated this PhD research from 2009 by conducting the first regional exploration of the entire Khorramabad Valley.

A "Regional Study" or "Wide viewing" as the main principal of the current research have been the main focuse of this PhD theis as one of the most important problem in the study area. Aquick observation into the previous research works in the Khorramabad Valley, shows scattered explorations and excavations with preliminary and discontinouity of publishing the results. Except for Frank Hole and Kent Flannery, who tried to understand the regional occupation and settlement patterns of the Khorramabad Valley, which was unfortunately limited to few preliminary results (that could be due to the mentioned accessibility problem that caused the discontinuity of research which is perhaps a common problem forany foreign scholar working abroad). Furtheremore, other works have been mostly surface findings reports or research on a specific locality (for example excavations at Yafteh Cave). Although Yafteh Cave has been quite well studied, however, due to absence of Midle Paleolithic seguence there, it provided limited information in understanding the transition from Middle to Upper Paleolithic of Khorramabad sites. Elsewhere in the Zagros, the other well studied cave of Ghar-e-Boof does not show Mousterian remains. The only remaining excavated sites in the Iranian Zagros that contain Middle and Upper Paleolithic sequences are the Warwasi rock shelter, Kobeh Cave, Shanidar Cave and Ghar-e-Khar. However, due to coarse excavations at that time and absence of chronometric data for some of them, they offer a limited information for the transition from one to another. Referring to the above problems adetailed description of the Zagros significant as one of the strong holders of human occupation during at least the middle Pleistocene onwards has remained poorly understood. Moreover, despite all the compliments and discussion on the significance of the Zagros in all the published data, a global position for the Zagros Mountains sites have not been stablished.

Despite the mentioned major problems, this PhD thesis initiated with otheraims to address and improve the following specific problems

- As a general concept, compared to the long time studies on European and Levantine sites, scarcity of Paleolithic research works in Iran is evident. So, apart from the cited issues, scarcity of comprehensive field works and researches is responsible for not being able to stablish a clear picture of Iranian Paleolithic and its position in the global scale. The current PhD research and the ongoing research project is an attempt to fill some of the gaps and to push forward our understanding of Khorramabad sites and their role in human evolution studies in this part of the world.
- Lack of complete reports from the earlier excavations and discontinuity of the works conducted by foreign researchers which were limited to preliminary and scattered field reports, more specifically those from 1960´s, as well as difficulties to access to the recovered materials from their excavation, raise the need for carrying out more field works using modern techniques for being able to assess and address some of issues related to Paleolithic occupation and settlement patterns of the region. In this scenario, lack of long-term and goal-oriented researches is evident.
- Absence of a position for the Zagros sites and in specific, Khorramabad localities in the global Paleolithic studies, seems to be another problem. Going through all the published results, lack of new/modern dating techniques and absence of reliable dates is clear.

  A solid age for the beginning or ending of Middle and Upper Paleolithic of the studied sites has not been fulfilled. We do not know the true age of starting or ending time in none of the studied sites, not only in the Khorramabad region but in all over Zagros. It is therefore, one of the important goal for this study was to achieve reliable dates for stablishment of a chronometric and if possible a byosin model for bio-chronological studies in the area.

- Lack of interdisciplinary and multuidisiplinary studies such as functional analysis of stone tools, experimental *vs* archaeological comparisons, statistical analysis, studies on faunal and flora remains for understanding the Paleoenvironment and sunbsistance patterns etc is another weak point of the studied sites. For this, in this PhD research along with the ongoing research project, we have distributed the recovered materials to different experts from Spanish and other European universities and institutes and building up a solid team for further studies.
- Despite all the efforts by pioneering researchers, lack of reliable evidence to show the transitional phenomenon from Middle to Upper Paleolithic, or in another word, information about the last Neanderthals and emergence of Modern humans in this particular area can be clearly seen. For this, finding site/sites containg both Middle and Upper Paleolithic was the major goal of this research work.

There are much more problems regarding Paleolithic studies of the study area that need to be stated. Some of them are listed below, and for sure would require advanced technologies and techniques.

- *Paleoenvironment*
- How much we know about paleoenvironment of the area?
- What kind of vegetation and fauna were exploited by hunters and gatherers in this area?
- How paleoenvironment study of the area can provide us information on the annual or seasonal uses of these caves and rock shelters?
- To find out the answers, study of pollen, charcoal and residue were taken into account in this research.
- *Palaeontology*

In this respect, lack of studies on large & micro mammals along withthe taphonomic analysis is evident.

- *Functional analysis* (Use-wear & residue analysis)

Looking to the long history of Paleolithic research works in the area, not a single functional analysis has been carried out on the recovered lithic materials. It is therefore, we do not know almost nothing regarding subsistent economic and technological use of the tools.

1-3: Research Questions and aims

Here by following the previous section "Statement of problem" I attempt to set the questions and aims of this research.

Chronology

Same as any other archaeological investigations, assessment or obtaining the chronology of the site/sites or study area is a fundamental principal in understanding the cultural sequences for their further contextual studies. In this situation, within the all excavated localities in the Khorramabad Valley, the obtained dates are limited only to two sites. The first one comes from Kunji Cave, obtained by Hole and Flannary in 1960´s and the second one is a series of dating from Yafteh Cave, first by Hole and Flannery in 1960´s and then by an Iranian-Belgian team. Hole and Flannery (1967:153) obtained two conventional radiocarbon dates from the second level, or "Main Component of the Mousterian," both yielding infinite dates in excess of 40,000 years B.P (Baumler and Speth 1993). They also manage to date the Upper Paleolithic layer of Yafteh, ranging from 21,000 to 40,000 uncal B.P (Hole and Flannery 1967). Otte and colleagues managed to obtain series of dates from the Upper Paleolithic sequence of Yafteh Cave from the charcoals recovered during two excavation seasons in 2005 and 2008. The dates from 2005 excavation are ranging from 24,470±280 to 35,450±600 uncal B.P (Otte et al. 2007). In their 2008 excavation, they again obtained new dates between 29252 ± 374 to 40510 ± 672 cal B.P (Otte et al. 2011).

In one hand, the dates obtained by C14 techniques prior to the 1970, could be drastically changed because of absence of reliable calibration at the time (Vahdati Nasab 2011), and on the other hand the dates from Kunji and Yafteh provide limited information for understanding the transition from Middle to Upper Paleolithic. Yafteh does not have the Middle Paleolithic sequence, and there is no evidence for Upper Paleolithic in Kunji!

So, the question concerning the transition and chronology of Khorramabad sites remained poorly understood. It is crucial and important to estimate and know when the Middle and Upper Paleolithic began in the area and when they ended?

So, one of the aim for this research was to find site/sites with uninterrupted archaeological sequences from Middle to Upper Paleolithic in the Khorramabad Valley and then dating them.

Finally, as a wideviewing, where the Khorramabad sites fit in the Paleolithic studies and where is its position in the Paleolithic world?

Furthermore, there are more specific and relevant questions such as:

- Besides chronometric issue, which types of studies could help in improving our understanding in regards to site/s functionality, tools functions, Paleoenvironment reconstruction, subsistence patterns, raw material sources and so on?
  In respect to functionality of the site/s this research aim to understand the technology of the lithic assemblages as well as identification of faunal remains along with taphonomic analysis to assess a general determination of the functionality of site/s. In regards to function of the tools, our ongoing research aims to provide information beyond the merely typological analysis performed so far on Iranian Paleolithic assemblages. For that, in the ongoing research we aim to implement use-wear analysis, for interpreting the function of stone tools in a more precise and reliable method.
  Based on paleoenvironmental and residue analysis, how was the vegetation and animal coverage as well as nutrition statues of the Paleolithic societies of the Khorramabad Valley? Is it possible to create a source of reference for understanding the climatic conditions of the central Zagros in general and the Khorramabd valley in specific? Concerning the raw material sources, one of the aim is to find out the most importantsources of raw materialsfor the manufactureofstone tools. Besides the continuesly reportedsecondary sources, are there primary sourceswhich wereusedin the manufacture ofstone artifacts?
- How to improve controversial dating issues of this region in order to establish more reliable chronology for its global position in Paleolithic studies? How to improve the transition hypothesis which was proposed as one of the oldest regions (out of Africa) where modern human was originated? Besides Yafteh cave, is there any other site with the same potentiality in providing more information about this transition hypothesis? To do so, in this research we aim to perform test pits in different sites to collect enough material for the relevant studies.

1-4: Hypothesis

Continuation of goal-oriented and wide-viewing studies with appropriate fieldwork and subsequent multidisciplinary researches in the region with its enormous potential might furnish crucial data to investigate the MP-UP transition in the Zagros and in the Middle East by extension. Implementing a regional study (including test excavations) might lead us to identify sites with archaeological sequences containing both Middle and Upper Paleolithic. This would certainly provide important information to assess and determine a reliable chronological reference for the Khorramabad sites and help in understanding the transitional phenomenon for the area and beyond.

- Continuation of studying the micro-faunal remains, archaeobotanical and residue analysis as a combined and complementary studies could help in understanding more about the environmental condition and nutrition of the Paleolithic societies lived in the Khorramabad Valley. Concerning the residue analysis, continuation of this type of analysis is likely to take further advantage of this technique, not only the Khorramabad sites but in other parts of Iranian Paleolithic. It may also play an important role in techno-morphological studies as a complementary technique.
- Considering Kaldar's strategic situation as a site located in the protected zone of Wild Life Century which is directly protecting it from the smugglers of cultural heritage and presence of undisturbed living-floors, might place it as one of the most important and untouched site in the Khorramabad Valley. It is therefore not unlikely that after obtaining the dating results, this site may contain a continuous succession from Middle Paleolithic to the Neolithic time.
- The high amount of chert materials from the Khorramabad River, (which passes almost from the center of the valley), is the result of flow from the conglomerate formation of the Makhmalkouh mountain to the valley, and therefore, probably this river could be the most important raw material sources for manufacturing the stone tools.
- Performing use-wear analysis on the recovered lithic assemblages could be a kind of evolutionary change not only for the Khorramabad sites, but the entire Iranian Paleolithic. It is therefore, implementing these types of analysis may lead us to create and define a kind of standardization that might allow us to overcome purely typological approaches undertaken so far in the Iranian Paleolithic studies.

- Despite the technological differences in manufacturing stone tools, closeness of sites in the Khorramabad (as a set of compact sites within the valley), might suggest a possibility to consider a common sequence from Pleistocene to Holocene for each of them. In this regard, Yafteh Cave might be an exceptional case with absence of Middle Paleolithic sequence. Finally, as a goal-oriented research, creating an International team under the Iranian leadership might provide the opportunity to overcome the unilateral research works conducted so far in the Iranian Paleolithic studies. As discussed in the statement of the problem, since the first survey of the Zagros by D. Garrod in 1930, (Garrod 1930), the only successful works that produced continues results are those where collaborative works initiated with the local Iranian teams and researchers such as Iranian-German and Iranian-Belgian teams. It is therefore, the Khorramabad Project led by author and Dr. Andreu Olle, by involving larger international team members from different universities and institutes, might led us creating one of the largest international project conducted in this region. These types of large collaborations also might widen more international collaborations and research works on the Iranian Paleolithic studies.

1-5: Exploration

In 2009, after obtaining the necessary permissions from the Lorestan Cultural Heritage, Handicraft and Tourism Organization, the first field-survey conducted by author benefiting from local residence. Exploration of the area started with the aim to evaluate the potential of sites in a future excavation perspective. To begin with, we explored the entire Khorramabad Valley by foreseeing the geographical situation of the sites for their future technological evaluation of the lithic industries from each geographical position. The idea was to find out whether geography of the sites produce different chronological and technological results or not. Therefore, we aimed to find sites within north, south, east and west. Our exploration initiated with the south part of the valley, where we visited and conducted a surface collection from Kunji Cave and Gar Arjeneh rock shelter which were investigated and excavated earlier in 1950 by Henry Field (Field 1951), Hole and Flannery in 1963 (Hole and Flannery 1967) and John Speth in 1969 (Speth 1971, Baumler and Speth 1993).Apart from these two known sites, we found more two small sites, one close to Kunji, another one in a form of series of very small rock shelters closed to each other near Gar Arjeneh. Despite presence of few lithic remains, however, none of these sites showed considerable archaeological deposits for further excavation.

In the east of Khorramabad Valley, there are four sites in Modbeh Mountain, consisting two small caves and four rock shelters. Due to sharp hills, test excavation at these sites needs a huge efforts as well as well equipped logistic team.

In the western part of the study area, we begin with Ghamari Cave, excavated earlier by Hole and Flannery, visited and studied materials from Gilvaran Cave, Yafteh Cave (excavated by Hole and Flannery and then Otte and colleagues). In the Yafteh Mountain, apart from Gachi rock shelter reported by Roustaei and colleagues (Roustaei et al 2002, 2004), we found two small caves and three rock shelters. Except one of the caves (which needs a big logistic team and man power for removing the collapsed rockes), assessing other sites depth of archaeological deposits need to be tested. It is worth mentioning here that, most of the caves and rock shelters in this part of the valley are located in the military zone, an area that seems to be impossible to visit due to heavy security system. However, while passing the area by Khorramabad – Kuh Dasht road, many of the caves can be seen from far. Geographically speaking, the area occupied by the army in this part, consist the biggest area of the Khorramabad Valley.

From the northern part, apart from Kaldar Cave, there are series of rock shelters at Makhmalkouh Mountain and perhaps several sites in the Sefid-Kuh Mountain, where a special permission from the Wild-Life Century is needed to access the area.

As a result, in superficial investigation, we tried to systematically record any archaeological remain, using 1 x 1 m grids created prior to surface collection. We used this method to evaluate or understand the scarcity and concentration zones of the lithic industries on surface for further spatial analysis. In order to obtain a general idea, a preliminary study of the recovered lithic materials was conducted. The recovered ithic artifacts from each site were classified in general groups such as flakes, balde and bladelets, retouched pieces and cortical pieces for further typological comparison with other localities. As a goal-oriented research, the superficial investigation initiated for the possibilities in finding out sites showing Middle and Upper Paleolithic surface evidence. The principal goal was specifically to find out lithic industries with technological characteristics of Mousterian and Baradostian/Aurignacian in a single site. Apart from the excavated (Kunji, Ghamari, Yafteh caves, Gar Arjeneh and Pa Sangar rock shelter) and reported sites (Gachi, Dozaleh, Dare Eshkaft, Gilvaran, such as Ghamari, Kunji, Yafteh, in the Khorramabad Valley, our exploration covered the entire Khorramabad Valley where there are large number of caves and rock shelters In addition to all the excavated sites, I attempt to visit and discover new sites with archaeological potential for future excavation.

Finally after a preliminary analysis of the recovered lithic industries from each geographical zone, considering other factors such as easier access to the sites, potential of archaeological deposits and evaluation of some of the earlier excavated sites, we selected Gar Arjeneh rock shelter from the south, Gilvaran and Ghamari Cave from the west and Kaldar Cave from the north for the test excavations. As mentioned, due to the sharp hills of the Modbeh Mountain, we abundant the idea of testing one of those eastern sites (Figure 1-5A).

- **Figure 1-5A: All the explored sites mentioned in the "Exploration Section"**

Chapter 2: Geographic Setting

2-1: Geography and Environment of Lorestan

Lorestan Province with an area of about 28,157 square kilometers is located in the West of Iran. The province is in the range between 36º, 23', to 36º, 40' , 46º degrees, 50' and 50º , 01'. This province shares the borders from the west to Ilam province, the north-west with Kermanshah province, from the north with Hamedan province, from north-east with Markazi province, in the east with Isfahan and in the west with Khuzestan province. According to the latest divisions of the provinces, Lorestan contain one of the ten major provinces, where Khorramabad is the capital city. Other cities are: Borujerd, Kuhdasht, Aligudarz, Azna, Delfan, Dorud, Poldokhtar, Aleshtar and Doure Chegeni.

Lorestan is formed in a combination of mountains, valleys and plains along with relatively dense vegetation and forests, a land where scattered human habitats can be observed in different parts of it. It is a collection of several ecosystems, each one with rivers, permanent springs, fountains, ponds, lakes, alpine and low mountains and several hilly areas. Lorestan contain 885,750 hectares of forest area, out of which 95/7% are the Iranian oak species so called *Querqus persica* (Management and Planning Organization of Lorestan province 2005).Topographically, the most important heights in Lorestan are Oshtorankuh with 4150m a.s.l, Garrin 3623m a.s.l, Sefidkuh 3150m a.s.l, Hashtad Pahloo 2800m a.s.l and Yafteh 2762m a.s.l, as well as plains such as Silakhor, Kuhdasht, Khorramabad and Aleshtar, along with numerous valleys and hills are shaping the topography of this part of the central Zagros. There are enormous natural caves and rock shelters in the Lorestan heights, where during different chronological times have been occupied since the Paleolithic times to the modern era. Some of the worth mentioning caves, rock shelters and open area sites are Kunji, Ghamari, Kaldar, Gilvaran, Ghazha, Bardsefid, Dosha, Mirmelas, Botkhana, Samsa, Aaliabad, Marjanem, Yafteh, Humian, Gar Arjeneh, Pasangar, Gachi, Dozaleh, Dare Eshkaft, etc.

The height difference is highly variable in different regions of Lorestan. For instance, 300 m a.s.l in the region of Poldokhtar height and more than 4,000 m a.s.l in the north-East. The extent of latitude created a huge climatic differences between the northern regions with cold climate and mountainous with the hot climate in the southern lowlands.

Animal species such as wild goat, wild sheep, wolf, jackal, fox, caracal, wild boar, leopard, Persian squirrel, porcupine and brown bears live in different forest areas of Lorestan.In addition, rodents, reptiles and birds, form a large part of this biodiversity.Aquatic habitats are also the proliferation of a variety of river fish and other aquatic species. The most important water artery of the province are Seimareh, Kashkan and Sezar rivers which come from combination of other rivers and along with permanent and seasonal springs create the major water resources of Lorestan. Lorestan, with an annual average of 450 mm rainfall, comes in the third highest rainfall zones of Iran after the Caspian basin and Urmia Lake basin (Figure 2-1A).

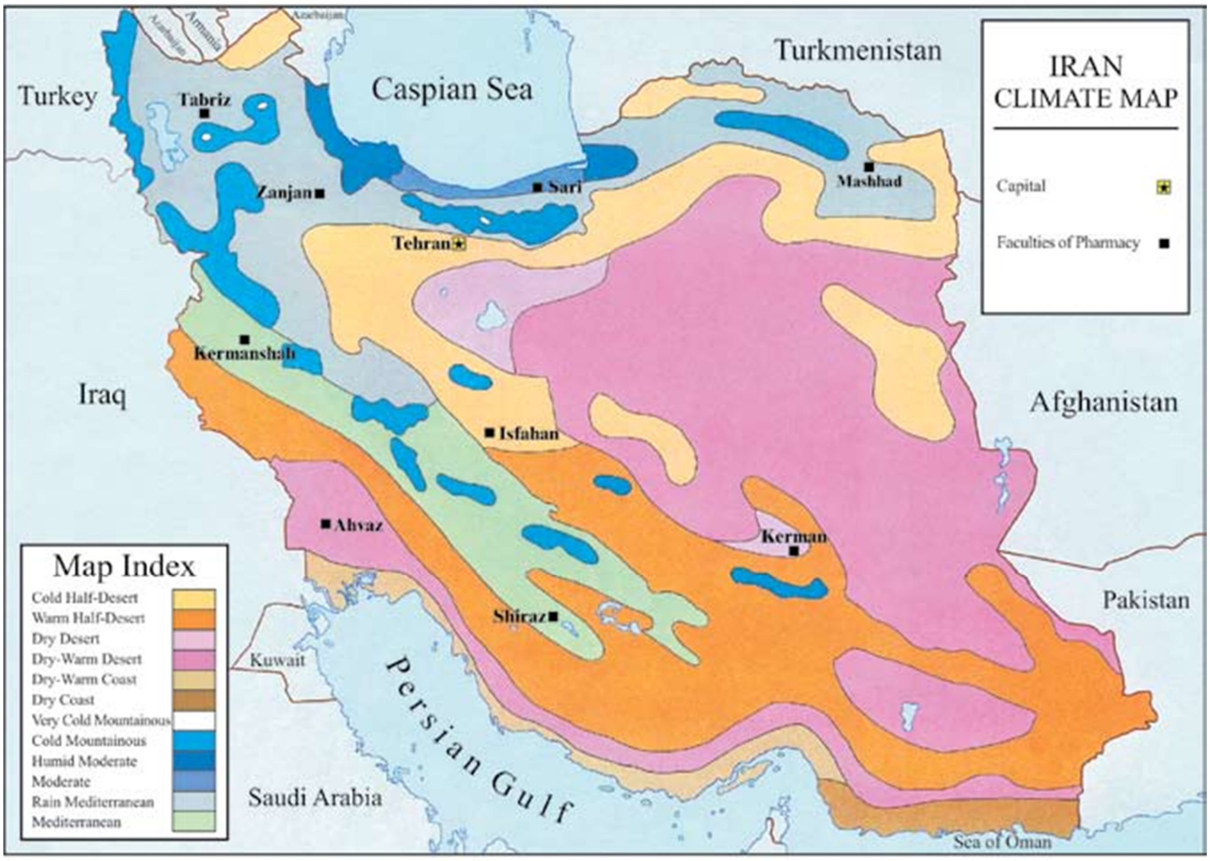


Figure 2-1A: Climatic condition of Iran.

Source:(*https://www.researchgate.net/publication/231608989_Herbal_Medicine_in_Iran***)**

2-2: Environmental conditions, geographic and water resources of Khorramabad

As the capital, Khorramabad city is located in the centre of the Lorestan province. From the north, it shares border with Boroujerd and Aleshtar cities, from the west to the cities of Chegeni and Kuh-Dasht, from the south with Plo-Dokhtar city and from the east with Douroud and Aligudarz cities. Khorramabad valley that makes up an important part of the city, is surrounded by the heights of Sefidkuh from west, Makhmalkuh from east and Modbeh from south. Its extreme north is limited to Shabihkhun strait, and its south extension reaches to the Koregah plain. Several low-lying natural heights could be seen in the north, centre and south of the valley. On one of these heights, the historical castle of Falak-ol-Aflak is located in the centre of the valley. The area of the Valley of Khorramabad based on calculations of the 25000/1 map is about 158 square kilometers. In this valley, the Khorramabad city and a number of subsidiary villages are formed in a North - South orientation.

Concerning water resources, Khorramabad Valley comes under Kashkan River basin which is one of the Karkhe River sub-basin. The river known as Khorramabad River or Galal, passes from the centre of the valley and eventually flows into the Kashkan River. There are several permanent springs out of which Golestan, Kiaw, Shahbaz, Darai and Gardaw-Bardina are the rich water resources and the most important factors shaping biological conditions of the area. Overall climate of todays Khorramabad comes into mild and sub-humid climatic condition. This is while the northern parts of it, is cooler than the southern part. (Figure 2-2A).

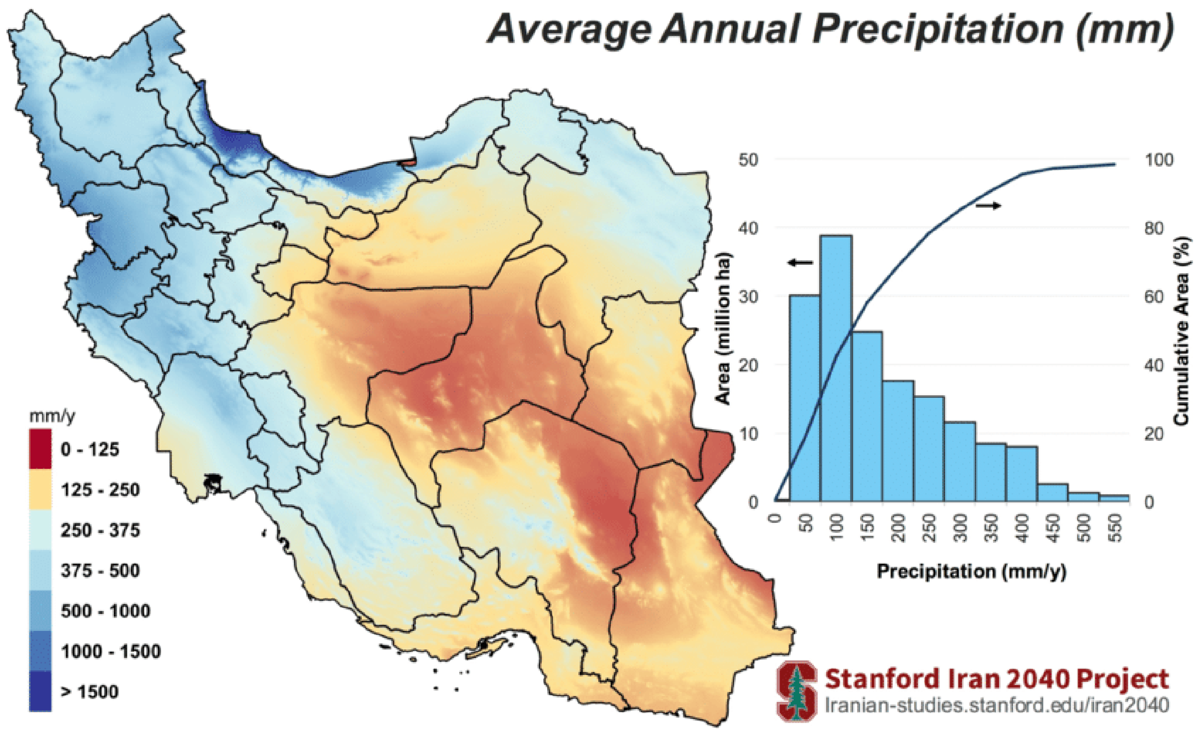


Figure 2-2A: Distribution of Iran's annual rainfall in mm.

Source: (https://www.researchgate.net/publication/311771175_Evaluation_of_Land_and_Precipitation_for_Agriculture_in_Iran)

2-3: Geology of Iranian Zagros, Khorramabad Region and Kaldar Cave Perimeter

Geologically and geomorphologically the Iranian Zagros Mountains consist of two major zones, the highland and the folded zones. These are parallel to each other, oriented from northeast to south. Being a part of larger geographical zones that extend from Alps to the Himalayas, the structure of these mountains seems to be young. Folded Zagros is a part of the Zagros tectonic zone which was built due to paleogeographical, special tectonic activities that segregated it from other geological units of Iran. Apart from its extension in Iraq, Syria and Turkey, largest part of the Zagros is in Iran that covers a wide territory from the west and south west. From the north-east it is limited to the Zagros Grand Fault. Its south east part in the north of Bandar Abbas is limited to Minab fault. Across the Zagros Mountains to the south and south-west continues to the Persian Gulf and the Arabian platform. Zagros zone in a southwest to northeast direction can be divided into three separate sub-zones of Khuzestan plain, folded belt and high Zagros.Through the activities of the petroleum industry, extensive knowledge has been gathered from the 'Simple' Zagros Fold Belt in front of the Mountain Front Fault (MFF), where most of the oil and gas fields have been discovered. In contrast to this, the more interior orogenic zones have been studied to a much lesser extent. The reasons for this may have been the higher degree of structural complexity, the often rugged surface topography resulting in reduced accessibility and the lack of adequate technology to cope with these complications (Bosold et al. 2005).

Zagros Mountains are mainly formed from limestone which plays the greatest role in the formation of a large number of caves and rock shelters. " It is suggested that apart from site formation and post-depositional processes, the local geological and geomorphological structure might also have had some influence on the distribution of prehistoric sites in the region" (Heydari 2007).

Archaeological information from these mountains clearly show the presence of human at least from the end of Middle Pleistocene (eg Braidwood, 1960; Hole and Flannery, 1967; Rosenberg, 1980; Biglari, 2001; Biglari and Heydari, 2001; Roustaei et al., 2004; Conard et al., 2005, Otte 2007). A quick observation on the location of important Paleolithic sites in a map show that most of the known localities in the Zagros Mountains, more specifically those from Kermanshah and Khorramabad region comes from the Massive Karstic Mountain System (MKMS).

As a large geological and archaeological investigation led by Heydari, several areas of the Iranian Zagros Mountains were covered to evaluate the impact of geology and geomorphology on archaeological site formation. This led to studying major parts of the highland and lowland of Zagros mainly the Kermanshah, Khorramabad, Ilam, and Gachsaran regions in the west central and southwest of the Zagros Mountains. In this study he suggests that, being located in the various karstic geomorphic terrains of these mountains, the geomorphological settings (e.g., morphology, bedrock, geometry, and local environmental aspects) of these sites are important controls on the nature and rate of sediment deposition (Heydari 2007).

The Karstic system consists of both thin and thick thrust sheets of massive limestone and is deeply dissected by drainage (Talebian and Jackson, 2002).According to Heydari, "The highland zone of the Zagros Mountains is an extremely complex system that has been folded, crushed, over thrusted, faulted, and in part, metamorphosed. The karsts are well developed within the massive limestone of this zone. A very common morphology here is the numerous escarpments that exist at the head of the thrust sheets. Steep, stream-cut ravines and gullies are present on nearly all the steeper mountain slopes" (Heydari 2007).

The general structure of the limestones of the massive Karstic mountain system is steep, moderately tight, broken, and complicated by steeply inclined thrust faults (Waltham and Ede, 1973).

Coming to our point, Khorramabad Valley is located in the highland zone which consist massive Karstic limestone sheets from south, southeast, southwest, northwest and only a conglomerate formation in its north eastern part where most of flints are washed away by Khorramabad River and flow to the center of the valley and continues to its southern part. Our observation of the Khorramabad sites is in agreement with Heydari 2007, that the majority of the Khorramabad caves and rock shelters are located halfway up the slope, because the lower parts of the MKMS are covered by a thick layer of fan sediments.

One of the interesting results from Heydari´s report, is that, the distribution of Middle and Upper Paleolithic sites seems to be in a way that the massive Karstic areas holds mainly the Middle Paleolithic sites, whereas the Upper Paleolithic and later occupational patterns appear also in the folded system zones. This is exactly the case for the Khorramabad sites. As was correctly mentioned by Heydari, some of other factors such as better availability of water and raw materials in the MKMS region and easier access between the mountains and lowlands, might have played a role in this site distribution (Heydari 2007).

"Most base camps are in chambered caves with a good view of the passing game. Often they are located at the boundary between two distinct hunting and gathering areas, such as the talus contact zone between the valley floor and one of the more extensive limestone ridge systems." (Hole and Flannery 1967: 162).

Geological setting of the Zagros with presence of speleothems offers great opportunities for paleoclimatic reconstructions by stable-isotopic analysis (Bar-Matthews et al., 1997). Lorestan geology in specific can be divided into two zones: a: Folded Sub-Zone and High Sub-Zone, b: Sanandej-Sirjan Zone.

Our study area comes under the Folded Zone. Kaldar and its perimeter comes under the Sefid-Kuh Mountain which is built from thin to medium limestones layers from Illam Formation that reaches upto the cave entrance. From the entrance to its ridge it is formed from Sarvak Formation.

The Sarvak Formation is in Bangestan group with the age from Middle Cretaceous (Albian – Turonian) mainly made from carbonate and a little shale and marl. This formation is the second major carbonate reservoir rocks in the Zagros Mountains and consist a huge platform range in the southern rim of the Neotethys. This formation name is derived from the Sarvak strait located in the north-western part of Behbahan city.

The Illam Formation is known from the extreme0 north-western part of the Kabir-Kuh in the Illam province. Same as the Sarvak formation, Illam formation also consist two facies: the Deep Pelagic and the Shallow Pelagic. Major part of the Shallow Pelagic zone is in Fars and Khozestan region. Wherease, Lorestan and our study area is in Deep Plagic zone.

Figure 2-3A: General view from Sefid-Kuh and a wide view of the Sarvak Formation

Figure 2-3B: Position of Sarvak and Illam formations from Kaldar Cave perimeter

Figure 2-3C: General view from Khorramabad conglomerate showing some part of modern city of Khorramabad

Figure 2-3D: Closer view from Khorramabad conglomerate

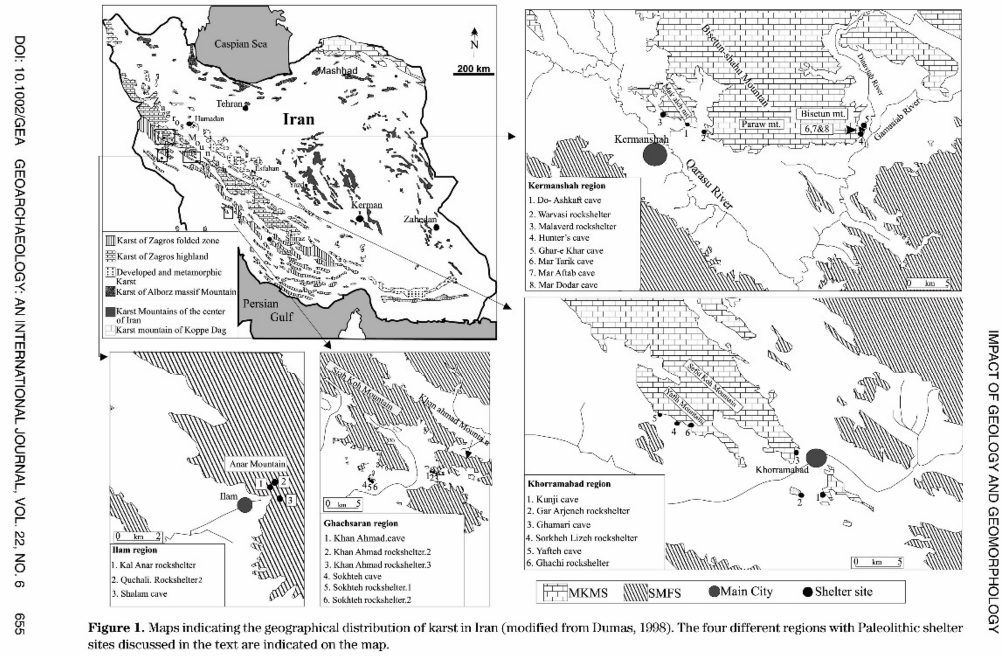


Figure 2-3E: Position of some of the Khorramabad Paleolithic sites located in Massive Karstic Mountain System (MKMS) from Heyradi 2007 geological study.

Chapter 3: Excavations at Gilvaran, Kaldar, Ghamari Caves and Gar Arjeneh Rock Shelter

3-1: Excavation at Gilvaran Cave

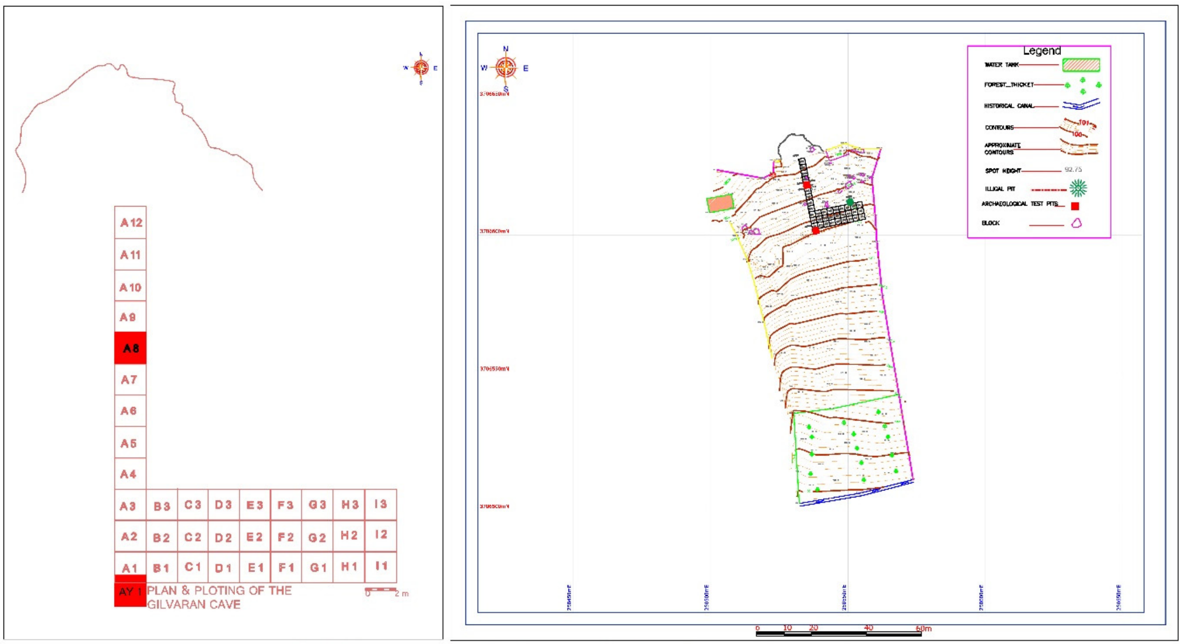
Gilvaran cave is situated in the northwestern part of the Khorramabad Valley and located in 48°18'56''E longitude, 32°28'12''N latitude, and about 1225 m a.s.l.It is 16 m long, 17 m wide and 7 m high. In 2002, the cave was officially included with record number 5971 into the Lorestan Cultural Heritage, Handicraft and Tourism Organization (LCHTO) archive as an Upper Paleolithic site by A. Parviz. The site has been also visited twice; by an Iranian team in 2002 and by international team in 2004, both lead by K. Roustaei.

As a goal-oriented research in a wide-view perspective, in this PhD research I tried to carry out a regional study to create a better assessment of the human occupation in the valley and to stablish an opportunity to evaluate previous studies in terms of chronology, occupational and settlement patterns, reconstruction of paleoenvironment etc. To do so, after a long and huge burucratic procedures I succeeded to obtain the necessary permissions to excavate, Gilvaran, Ghamari and Kaldar caves and Gar Arjeneh rock shelter. The selected areas for excavation at Gilvaran Cave was several meters outside the cave. This was due to lesser thickness of sediments inside the cave and more thickness outside. Therefore, prior to starting the actual excavation, predicting the rain and snowfalls during winter season, in the autumn of 2010 we put the first step and covered the archaeological deposit by creating an artificial plastic cover. Eventually, few days before starting the excavation we built a plastic tent for the rest of excavation season (Fig 3-1A).

Figure 3-1A: Preparation stages for protecting the archaeological sediments from winter rain fall.

The second step was to map and build the plan and plot for the archaeological sediment for future references. Due to the huge area of the deposit (approximately 1 hectare), we mapped the central area of the archaeological deposits parallel to the cave entrance. Furthermore, using a Total Station we prepared the topography of the cave and its archaeological and natural object from the slops in front of the cave and then drawn the plots of the trench within the topographic map for future references(Fig 3-1B and 3-1C).

Figure 3-1B (Mapping and plotting the archaeological deposits)



Detailed topography with the exact location of excavated test pits

Figure 3-1C: Topography of the cave and its outskirt area. Excat location of the excavated trenches is shown in red colour

Two days of extensive classes for the local excavation team was organized. The aim was to explain the excavation method, mainly the recording system of the objects and finally the goals of the excavation. In the class, I thought the excavation method and the recording system following the method that I have been thought during my participation in the excavations at the Atapuerca sites, where an interdisciplinary methodological model for more than 30 years, since the inception of its research team in 1997 has been performed. At this site, the methodology includes surface excavations that follow the stratigraphy, allowing recovery of all the archaeological items, as well as building a context in which to place the discoveries in relation to the occupational strategies followed by the cultural remains, the chronology, the taphonomy of the items and the sites, the palaeontology and so on.

Using this opportunity, I also aim to train the local members for a future perspective (Fig 3-1D).

Figure 3-1D: Training classes for the local excavators

Finally, from the drawn plans shown in the topographical map of the site, removed the recent superficial grasses and other recent dirt's and then trenches were ready for excavation (Fig 3-1E).

The same method was also followed in Ghamari and Kaldar caves and Gar Arjeneh rock shelter.

Figure 3-1E: Trench ready for excavation

3-1a: Excavation methodology

After fixing a datum point and setting the bench marks, we opened two 2 ×2 m trenches, away from the cave entrance and named them based on their locations in the maps (A8 and AY1). They are located 4 meters and 20 meters away from the dripline respectively. The excavation was conducted using two level-measurers for each trench for recording the archaeological finds. We dug spits of 5 cm within each archaeostratigraphic unit, as well as 3D recording of all findings. Layers and sub-layers were initially recognized by the sediment colour, variation in deposit density as well as consideration of diagnostic finds such as potsherds in the late Holocene as well as lithic industries from early Holocene to Pliestocene onwards. Samples for contextual studies, including sedimentology, paleontology, paleoenvironment (pollen, charcoal, seeds, and land snails) and dating (OSL tubes and charcoal) were systematically collected.

3-1b: Stratigraphy and archaeological context

Detailed information on stratigraphic sequence of both AY1 and A8 trench is shown in Bazgir et al. 2014 presented in this thesis. However, to provide some more information here, the AY1 trench showed one of the deepest stratigraphic sequence excavated so far in the Zagros Mountains. Except for Warwasi rock shelter located in the Kermanshah province that also showed a deep stratigraphy, as a cave setting, Gilvaran contains the deepest archaeological sedimentary deposit (Figures 3-1bA and 3-1bB). Moreover, as far as we know, this locality also holds the hugest archaeological deposit in the region. The archaeological deposit in front of this cave exceed one hectare, certainly with variation in depth in different areas. In addition, density of lithic artifacts within the archaeological sediment in Gilvaran Cave seems to be much more than any other sites we excavated in the Khorramabad Valley. This might show a longer occupational seasons at this cave.

- **Figure 3-1bA: The AY1 trench. It´s deep stratigraphy is clear in the photos**

Figure 3-1bB: Different views of the trench A8

3-1c: Lithic industry

This locality seems to be a suitable site for a long-term excavation plan that could provide great information, mostly in regards to lithic technological variabilities. Moreover, its Pliestocene sequence contains two thick layers belonging to Middle and Upper Paleolithic that provides a great opportunity for studying and understanding the transitional phases. Within the Middle Paleolithic lithic assemblage, presence of Tayac points and limaces might represent an early age of occupational timing. In the Upper Paleolithic sequence, presence of large number of diagnostic Baradostian lithic artifacts such as Arjeneh points, carrinated cores/scrappers as well as elongated blade and bladelets provides a great opportunity to understand the technological variabilities within the artifacts made by *Homo sapiens* in the region. Technologically, presence of wide variety of points in Gilvaran Cave, is an exceptional case among all other localities we excavated in the Khorramabad Valley.

A detailed description of the lithic industry of this locality can be found in Bazgir et al. 2014, presented here in chapter 3, sub-chapter 3-3e.

3-1d: Fanunal remains

Although faunal studies are still underway, however, the identified taxa based on stratigraphic positions from both AY1 and A8 trenches are presented here. A full description of the identified species and their contribution in the global context is presented in Bazgir et al. 2014. It is worth mentioning here that all the large mammals have been studied by Dr. Jan van der Made, one of the fixed team member of the Khorramabad Project.

***Equus* sp.**

A distal metacarpal belongs to *Equus*. It is much larger than those of *E. hydruntinus* and *E. hemionus* and must have belonged to a caballoid horse. It is also larger than the metacarpals of the Prezewalski horse. However, in the Pleistocene, there were larger cabaloid horses and it must have belonged to one of these species.

Rhinocerotidae indet?

What seems to be an enamel fragment has a thickness of about 2.7 mm. The surface is not rugose, resembling in this the tooth enamel of *Stephanorhinus kirchbergensis* or *Rhinoceros unicornis*. The specimen was figured by Bazgir et al. (2014, figure 8/2) and tentatively assigned to an unidentified species of rhinoceros.

Sus scrofa

Small molar fragments indicate the presence of a suid. Today and from the Late Pleistocene the only suid known from the area is *Sus scrofa* and its certain presence in Kaldar Cave is testified by a lower male canine with the characteristic section of this species.

***Capreolus* sp.**

The presence of a small ruminant is indicated by several bone fragments, including the shaft of a metatarsal, a patella and a sesamoid bone. These bones show features, different from their homologues in *Gazella* or other small bovids and similar to those in *Capreolus*. The sesamoid was figured by Bazgir et al. (2014, SOM figure 14/1) and its morphology and size discussed. The specimen is an axial sesamoid articulating with the first phalanx. Axial sesamoids of small bovids tend to have a sharper angle between the axial and plantar sides, while cervids tend to be more rounded. The specimen from Gilvaran resembles the *Capreolus* sesamoids in morphology and is in the upper size range of the West European *C. capreolus.* The patella from Gilvaran is a little larger than those of recent *Capreolus capreolus* from Western Europe with which it was compared. The fossils were assigned to *Capreolus* sp. (Bazgir et al., 2014).

Cervidae indet. cf. *Cervus elaphus*

A fragmentary lumbar vertebra (Bazgir et al., 2014, figure 8/4) resembles the vertebra of *Cervus elaphus* in size and morphology and was tentatively assigned to that species. The presence of this species in the nearby Kaldar Cave has now been demonstrated and it is likely that it was also present in Gilvaran Cave.

Bovini indet.

The presence of a bovine of very large size is indicated by a second upper premolar and numerous tooth fragments and a sesamoid bone. The premolar was figured by Bazgir et al. (2014, figure 8/6) and assigned to Bovini indet.

Caprini indet. cf. *Capra aegagrus*

Some lower incisors wre figured by Bazgir et al. (2014, SOM figure 3/2 and 3/4) and were assigned to *Capra* sp. cf. *C. aegagrus.*

3-1eA: Functional studies

The main aim of these analyses was firstly introducing these types of analyses in Iranian Paleolithic studies and secondly to overcome purely techno-typological conducted so far on Iranian lithic assemblages. Materials used here are recovered flints from our excavations at Khorramabad sites.

We used different methods and techniques such as metallographic microscope Zeiss Axio Scope A1 and Digital 3D Hirox microscope and Scanning Electron Microscopy (ESEM FEI Quanta 600). For the metallographic microscope, the images were taken at 50, 100, 200 and 500x, which leads to horizontal field witdh (HFW) of 2280, 1146, 573 and 229 µ respectively.

Additionally, we conducted compositional analyses by means of the EDS associated to the ESEM, and some samples were analysed at ICFO (Barcelona) by means of Raman and FTIR. The residue analysis carried out with the latter techniques are underway, therefore, here I present some examples of our observations under optical microscopes. Preliminary results show high potential of the lithic assemblages indicating possible origin of traces such as hafting, fractures likely produced by the use of projectiles and several polish and striations from their possible use in different functional activities.

As a part of ongoing multidisciplinary studies, we carried out a comprehensive documentation of usewear, residues, macro and micro fractures using metallographic microscope Zeiss Aixo Scope A1 and Digital 3D Hirox microscope. Some examples of preliminary documentations are provided here (Figs 3-1eA to 3-1eO) as well as in the forthcoming similar sub-headings for other sites studied in this thesis. All the presented examples are the preliminary documentation of the functional analysis. These documentations are the primary stage of our ongoing studies, more detailed analysis and their interpretations is underway. The main aim of these studies is to reconstruct the subsistent economic and technological use of stone tools in the sites of Khorramabad Valley. We initiated the functional analysis on the recovered materials with several aims. As a general practice, the first step was to check the tools surfaces under optical microscopes to find out their potential for further use-wear or residue analysis or both. Our preliminary observation shows that, among all the excavated sites, Kaldar assemblage shows a much better preservation of both usewears and residues. Other localities, mainly Gilvaran assemblage provide more usewears and fewer residues.

3-1eB: Antracology:

I provided here more details from our anthrachological analysis on the recovered charcoals from Gilvaran and Kaldar caves. These information are important in a sense to understand more the paleoenvironment condition of the region as well as supportive information for further assessment of the region climate by complementary analysis such as faunal studies. The mentioned information has been prepared as an article for publication in the journal of Comptes Rendus Palevol. The antracology submitted manuscript is presented in <u>chapter 3, sub-chapter 3-4g</u>, immediately after <u>¨Publication 3¨</u>.

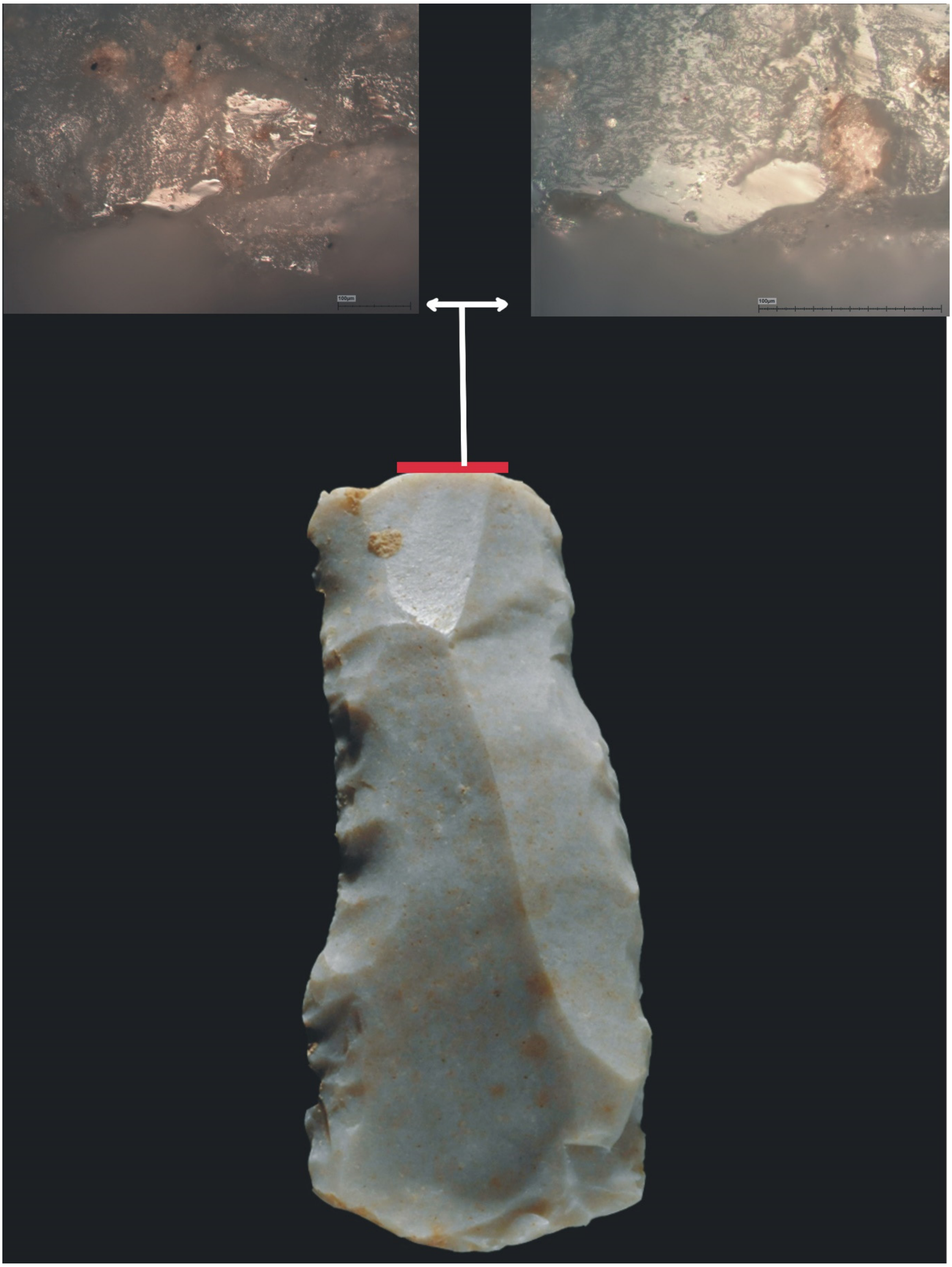


Figure 3-1eA: Heavy polish on distal part of a retouched double scraper (same point shown at 100 mag on left and 500 mag on right) (Middle Paleolithic – Layer 5).

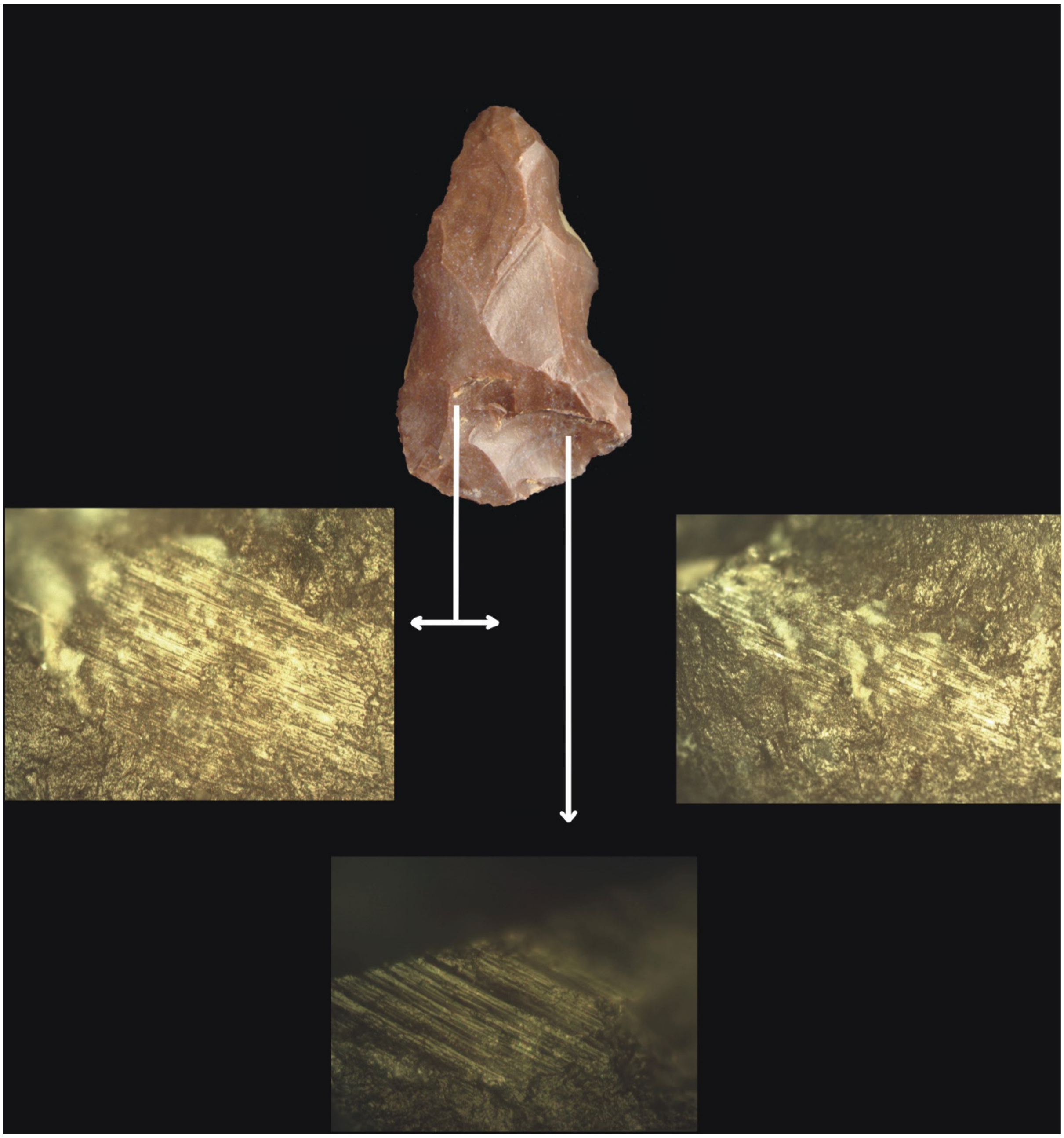


Figure 3-1eB: Heavy deep diagonal striations, parallel to each other on the proximal part of a Tayac point, likely related to tool hafting. (Middle Paleolithic – Layer 5).

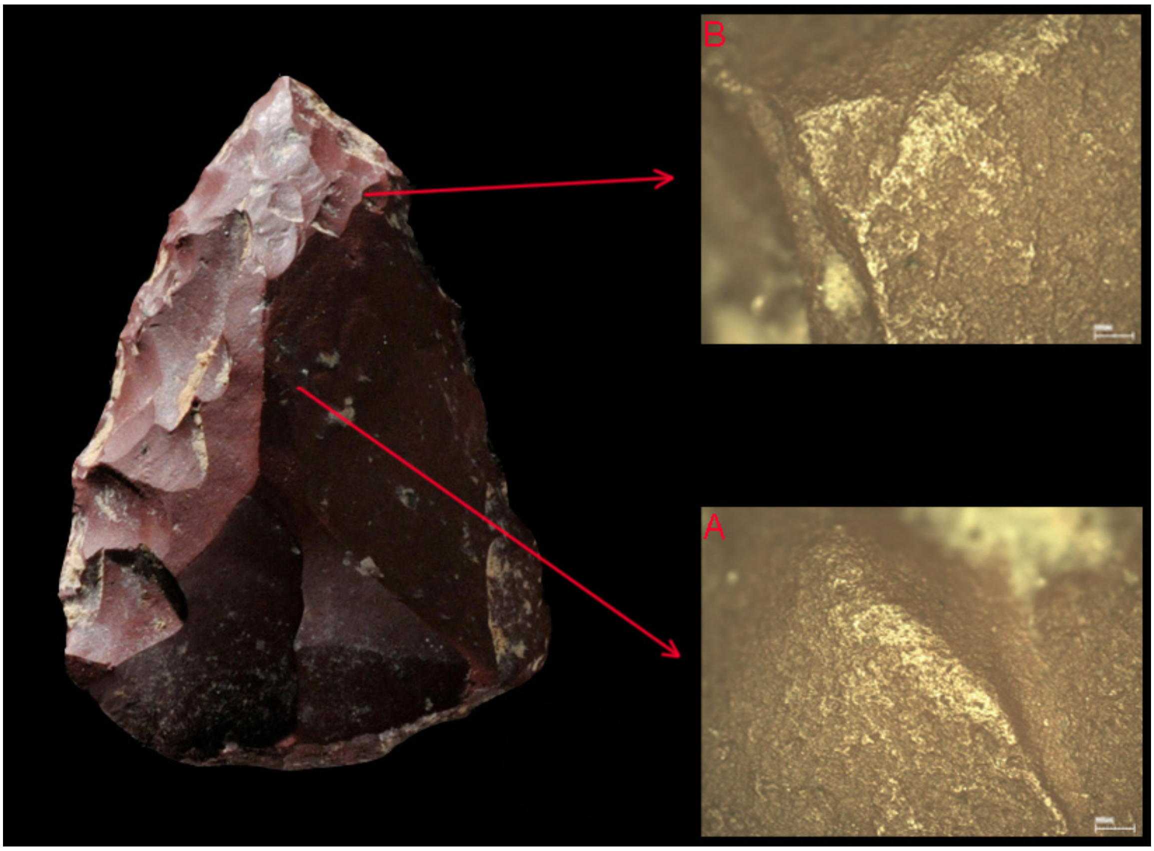


Figure 3-1eC: Polish on distal and medial parts of a Mousterian point (Middle Paleolithic – Layer 5).

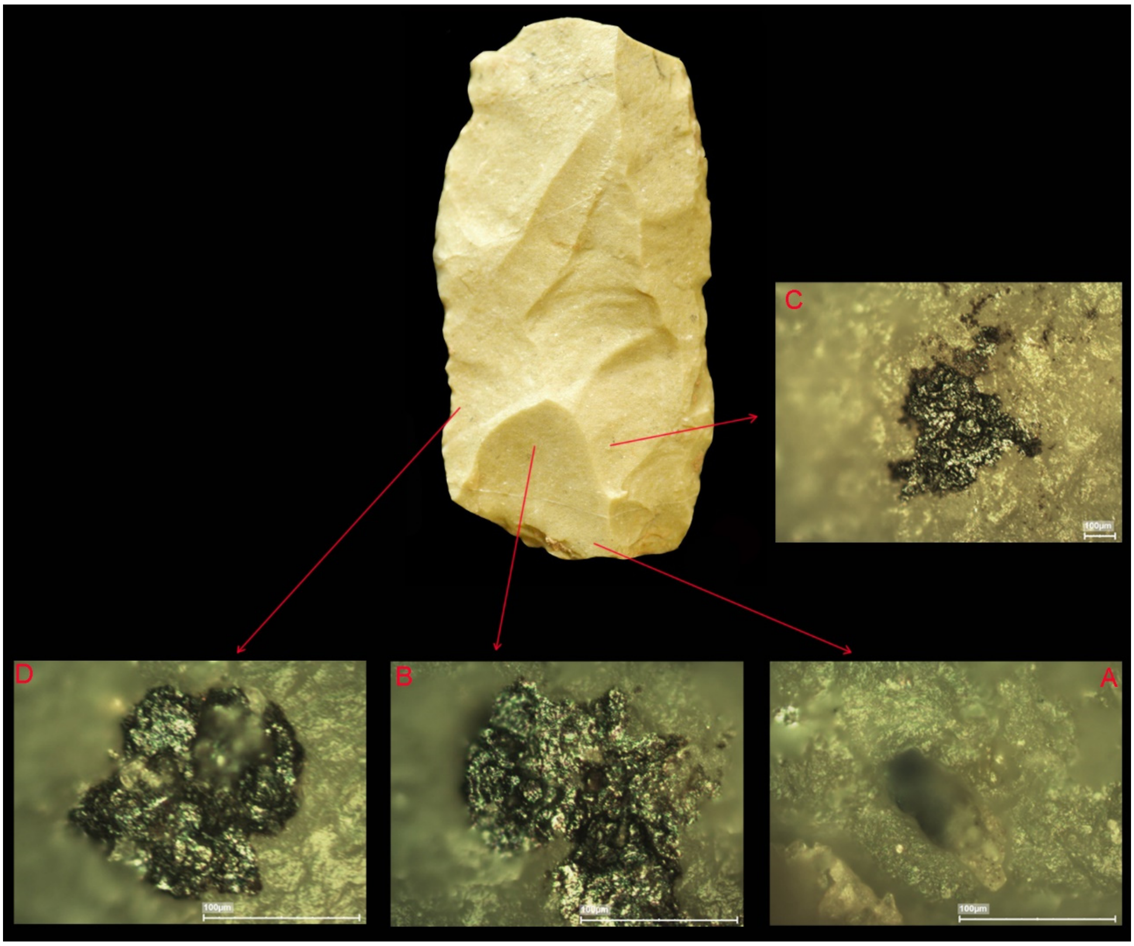


Figure 3-1eD: Black residues on proximal part of a Levallois flake (Middle Paleolithic – Layer 5).

Figure 3-1eE: Macro fractures on distal part of a broken retouched Levallois Point (Middle Paleolithic – Layer 5).

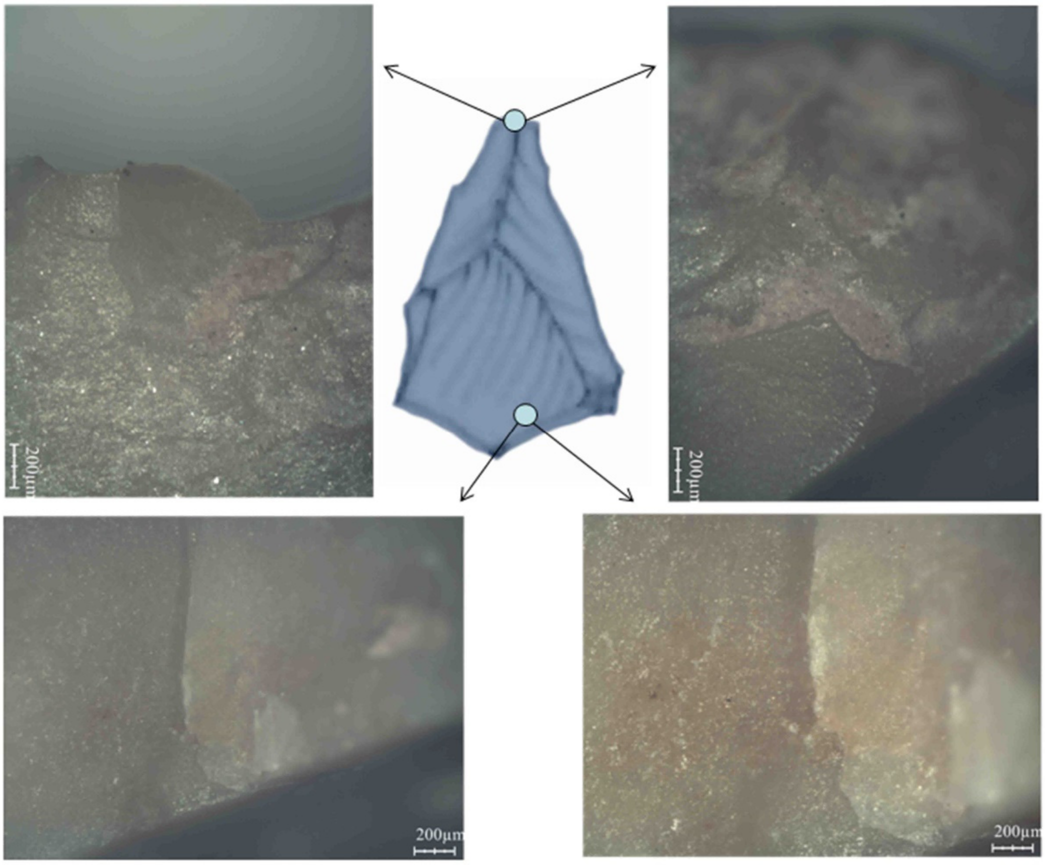


Figure 3-1eF: Macro fractures on distalandproximal parts of a Levallois point (Middle Paleolithic – Layer 5).

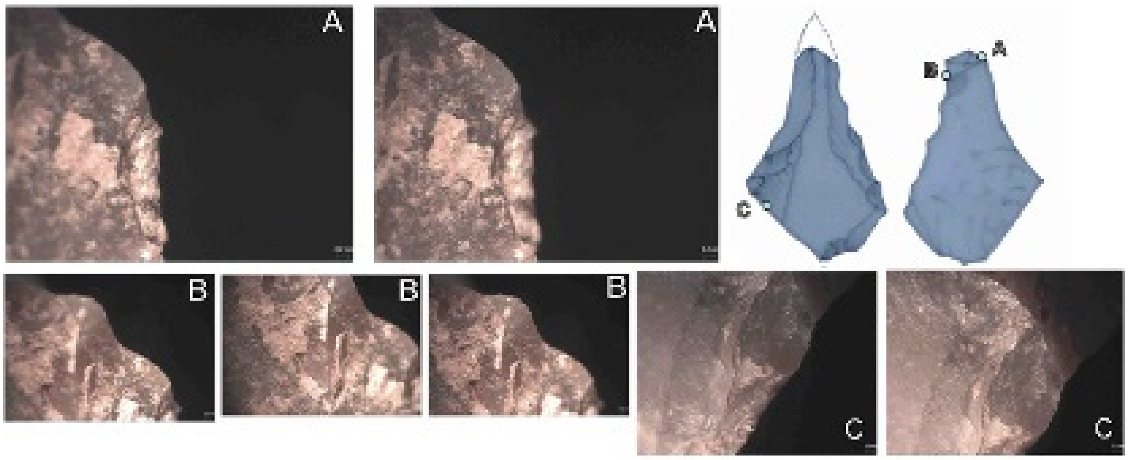


Figure 3-1eG: Macro fractures on distal and proximal parts of a Levallois point (Middle Paleolithic – Layer 5).

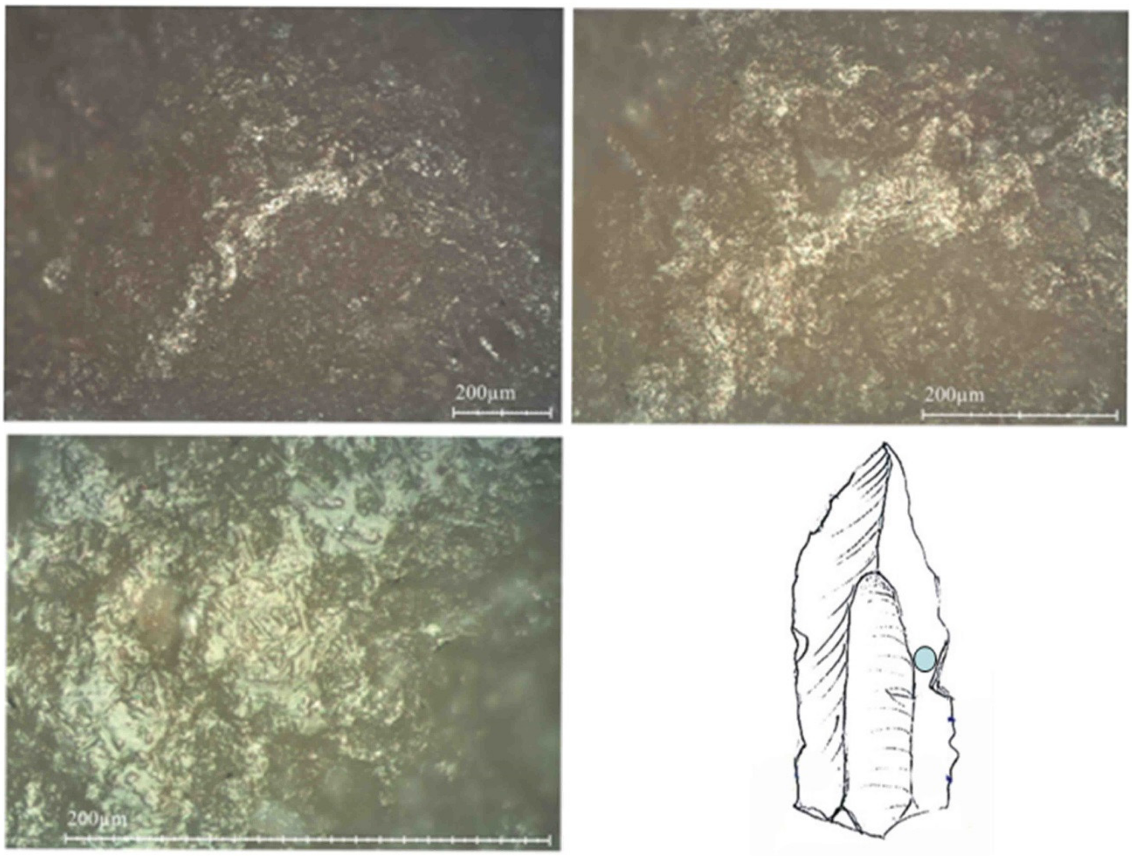


Figure 3-1eH: Polish on medial part of a Levallois point (Middle Paleolithic – Layer 5).

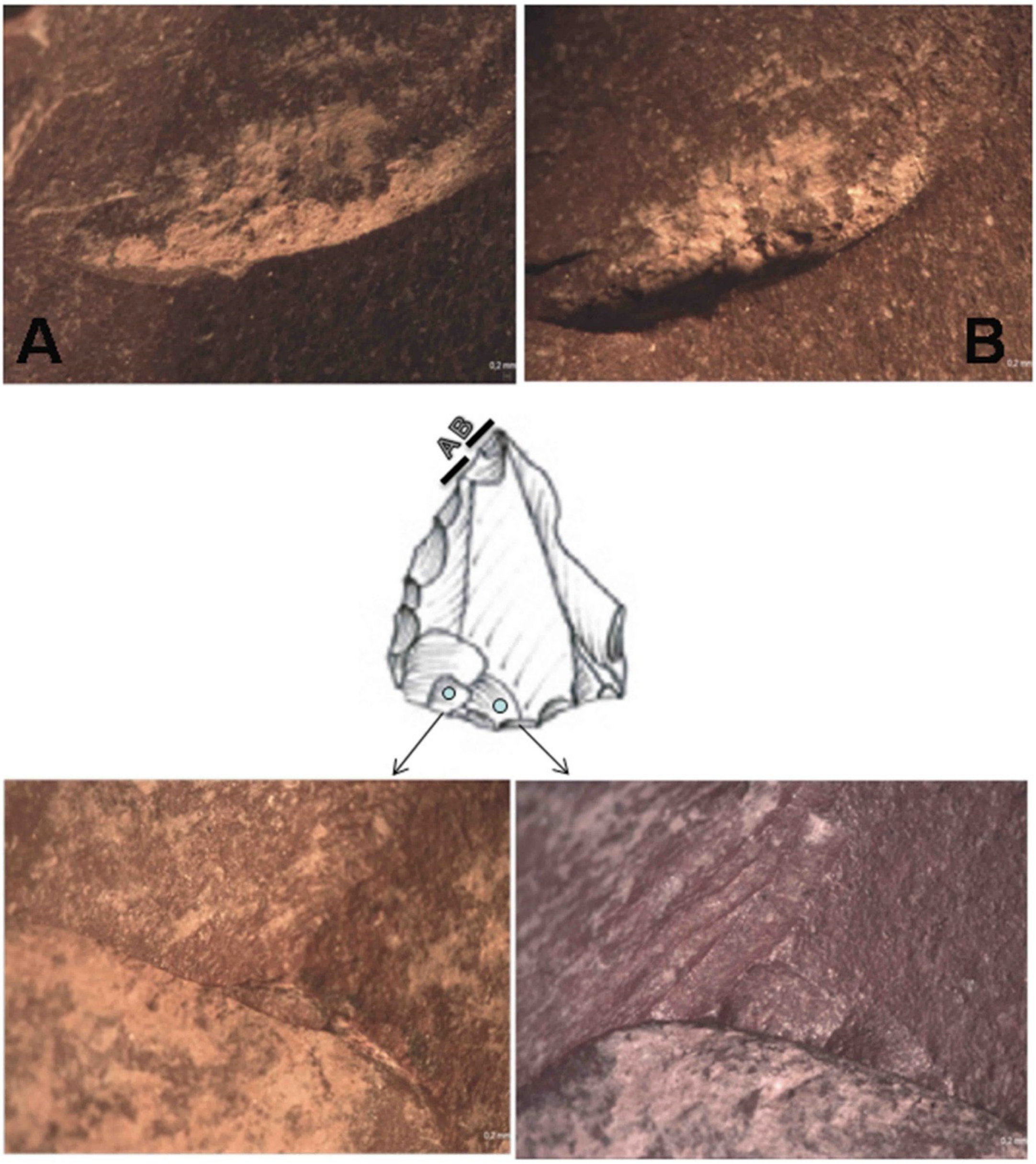


Figure 3-1eI: Macro fractures on distal and proximal parts of a retouchedLevallois point (Middle Paleolithic – Layer 5).

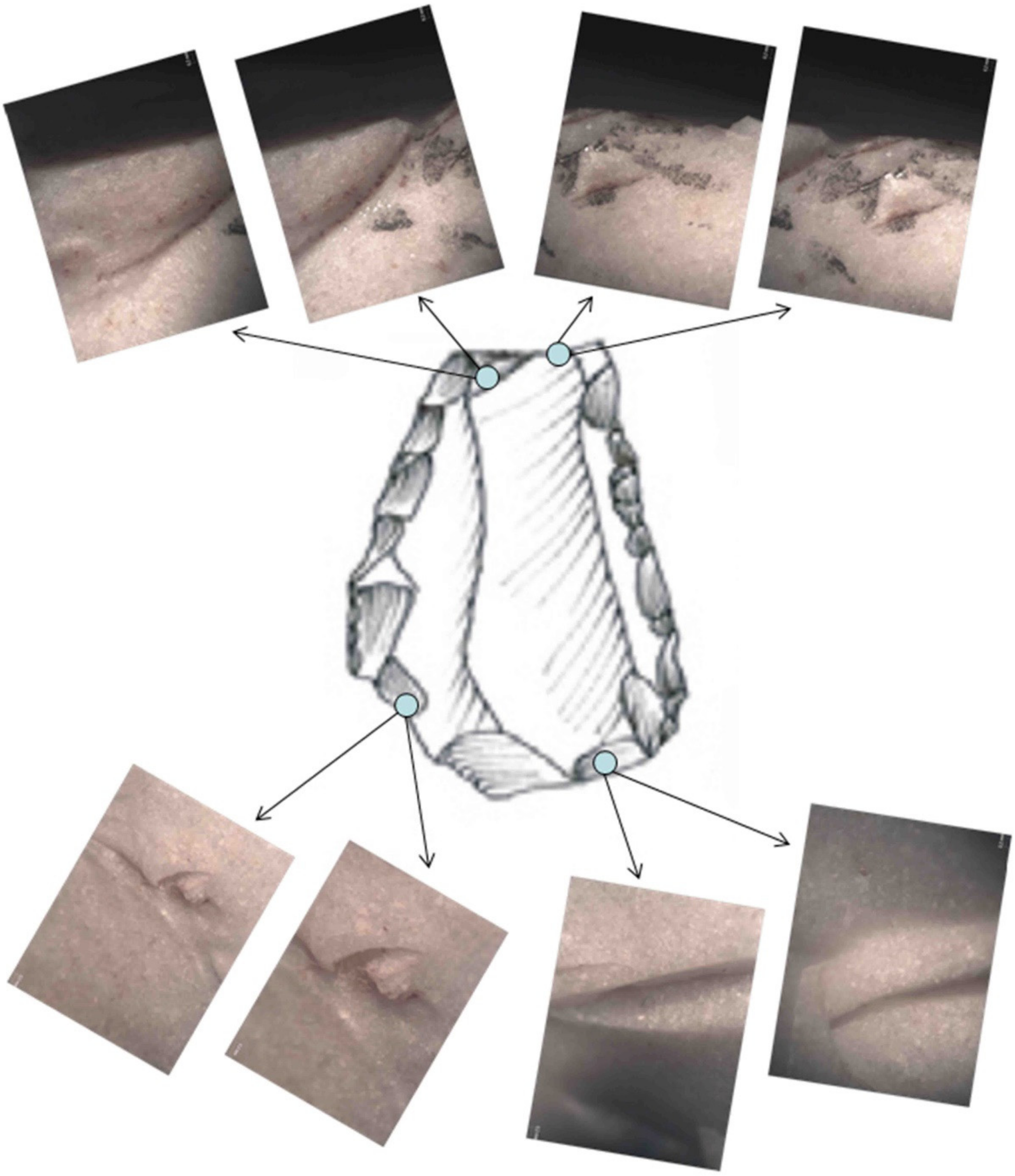


Figure 3-1eJ: Macro fractures on distal and proximal parts of a retouched Levallois point (Middle Paleolithic – Layer 5).

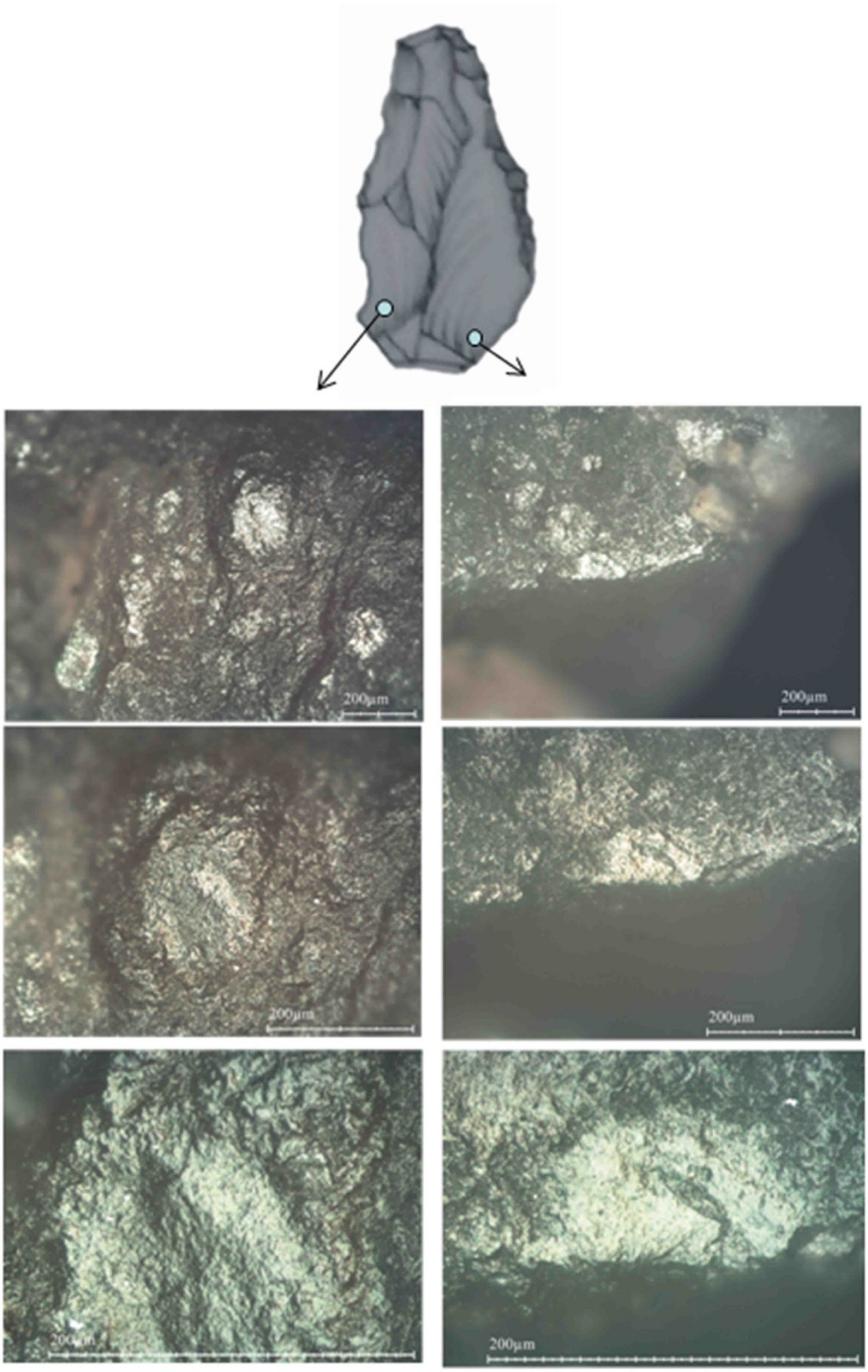


Figure 3-1eK: Polish on proximal part of a retouched Levallois pointon right side row same point from 50 to 500 mag. (at 50, 100 and 500 mag) (Middle Paleolithic – Layer 5).

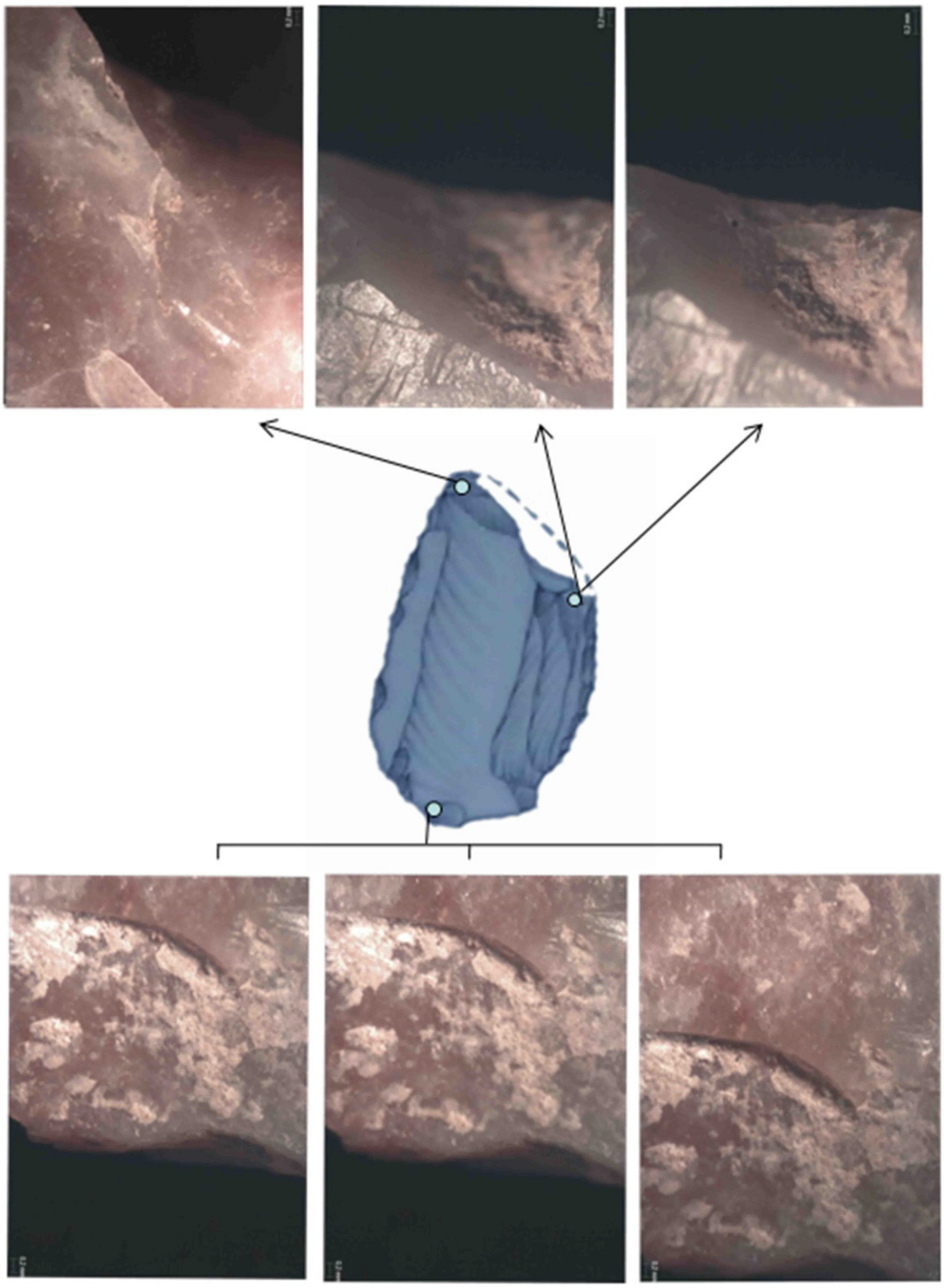


Figure 3-1eL: Macro fractures on distal and proximal parts of aLevallois point (Middle Paleolithic – Layer 5).

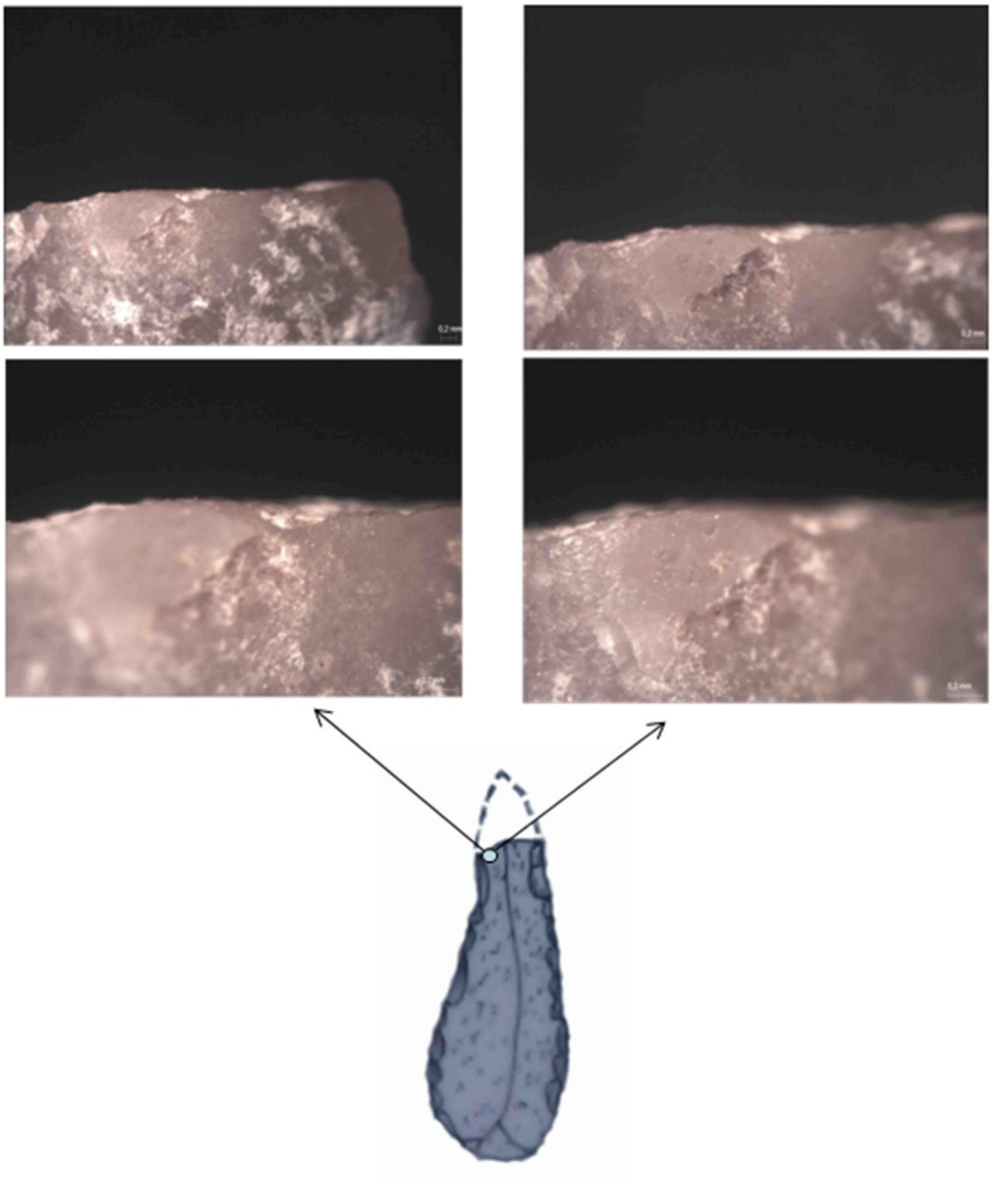


Figure 3-1eM: Macro fracture on distal part of a broken Arjeneh point (Upper Paleolithic – Layer 4).

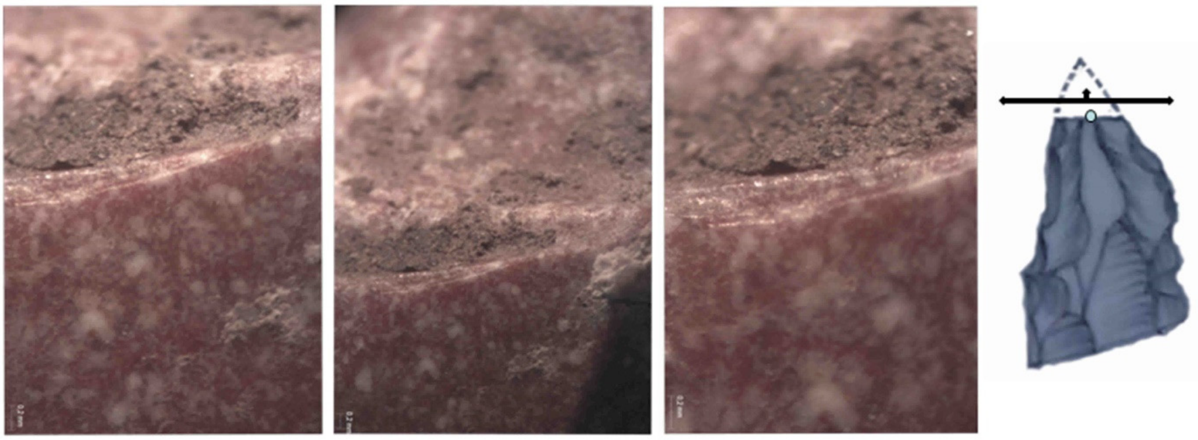


Figure 3-1eN: Macro fracture on distal part of a broken bladelet point (Upper Paleolithic – Layer 4).

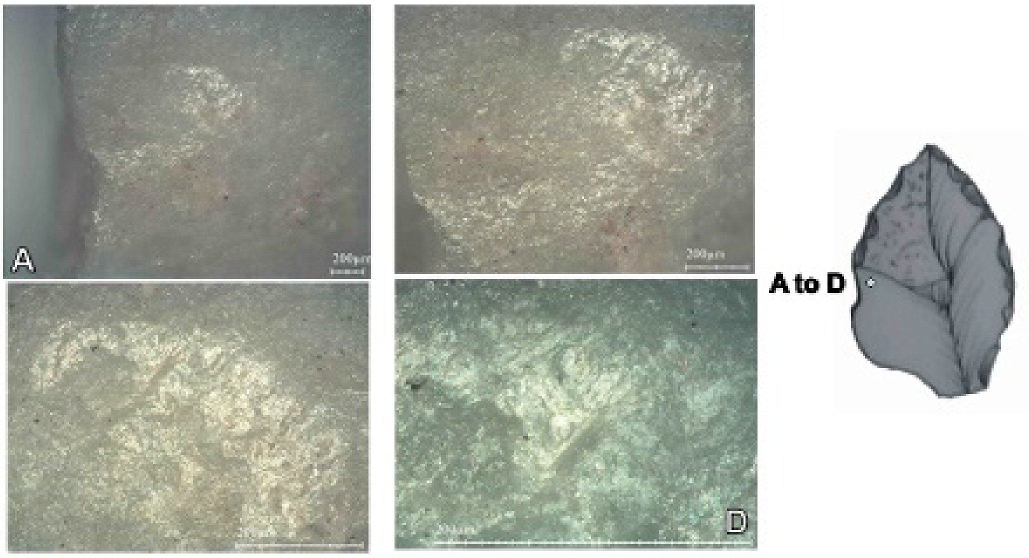


Figure 3-1eO: Polish on medial part of a retouched pointshowing from 50 to 500 (50, 100, 200, 500) magnification under optical microscope (Upper Paleolithic – Layer 4).

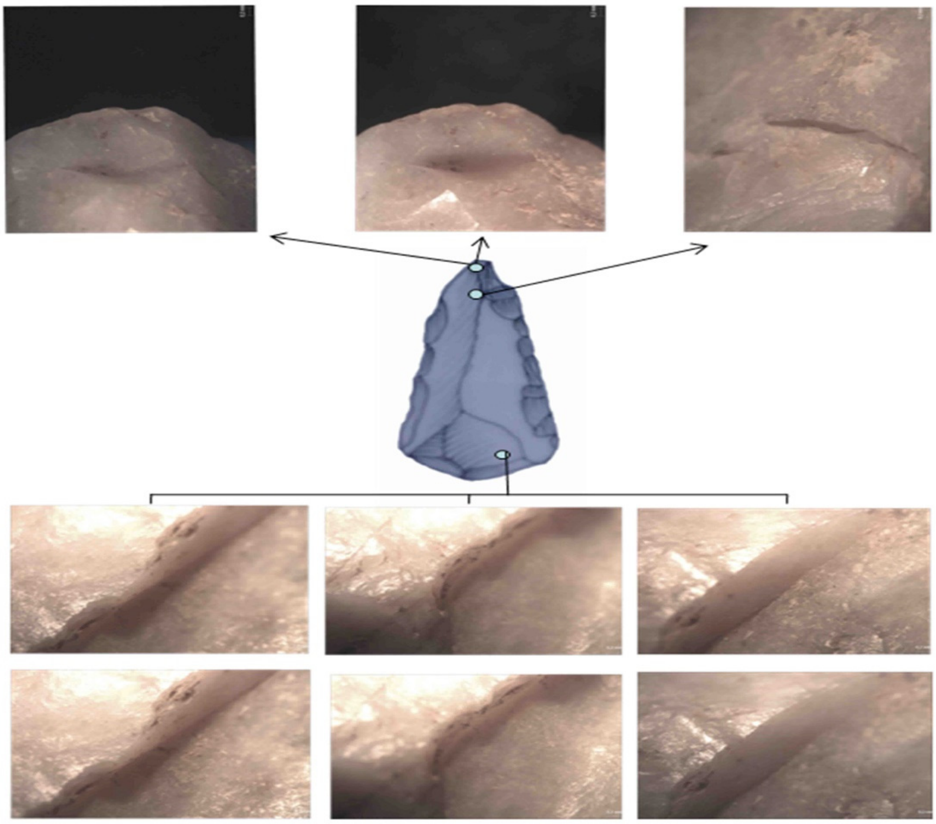


Figure 3-1eP: Macro fractures on distal and proximal parts of a Mousterian point (Middle Paleolithic – Layer 5).

3-2: Excavation at Ghamari Cave

This site is located in 48◦:20_:56__E longitude, 33◦:29◦:31N latitude and 1305 m a.s.l. As a part of extensive excavation program led by Frank Hole and Kent Flannary, this cave was among the sites excavated by them in 1960´s. We selected this locality for a test excavation with the several aims such as evaluation of previous studies, geographic position of the site for comparision with the other selected sites in different geographic locations within the valley, having no access to previous excavated materials and finally to investigate the fill of the cave with a modern excavation method. (Figure 3-2A). For several reasons, mainly due to a sharp hill from the Khorramabad base to the cave entrance, perhaps excavating Ghamari Cave might be considered as one of the most difficult field investigation in the Khorramabad Valley. This make it more difficult concerning logistic preparation and transportation of excavation materials, water sieving of the sediments, lighting system etc.

However, prior to starting the actual excavation, we investigated all the three chambers of the cave. After plotting and maping all the chambers, we estimated the best place for our test excavation (Fig 3-2B).

The selected area for our excavation is located in the first chamber of the cave, where there is a large surface of archaeological sedimentary deposit. The second chamber seems to be suitable for faunal remains investigation. This chamber contain much less archaeological deposit in its south eastern corner. The third chamber does not have any archaeological deposit. Same as Gilvaran Cave, a topography of the cave for a future reference was carried out (Fig 3-2C).

Figure 3-2A: General view of the Ghamari Cave and its sharp slope in front of the site

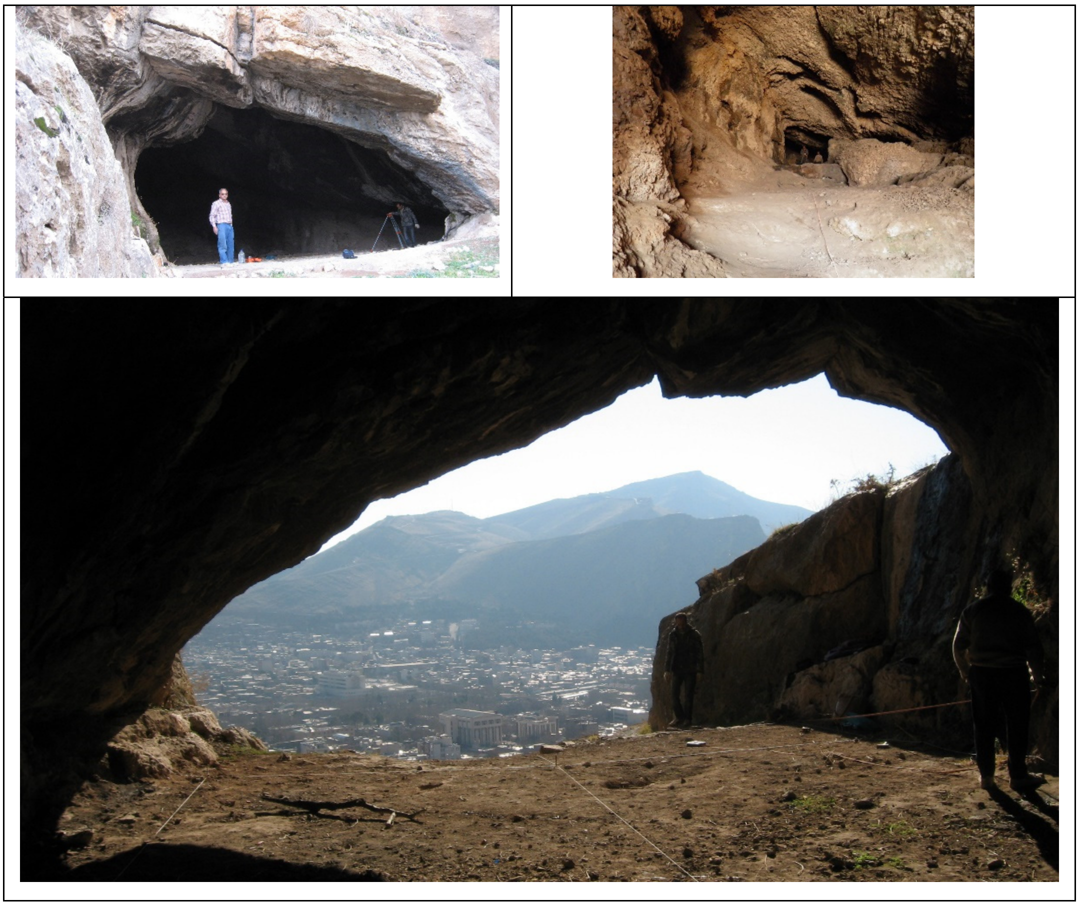
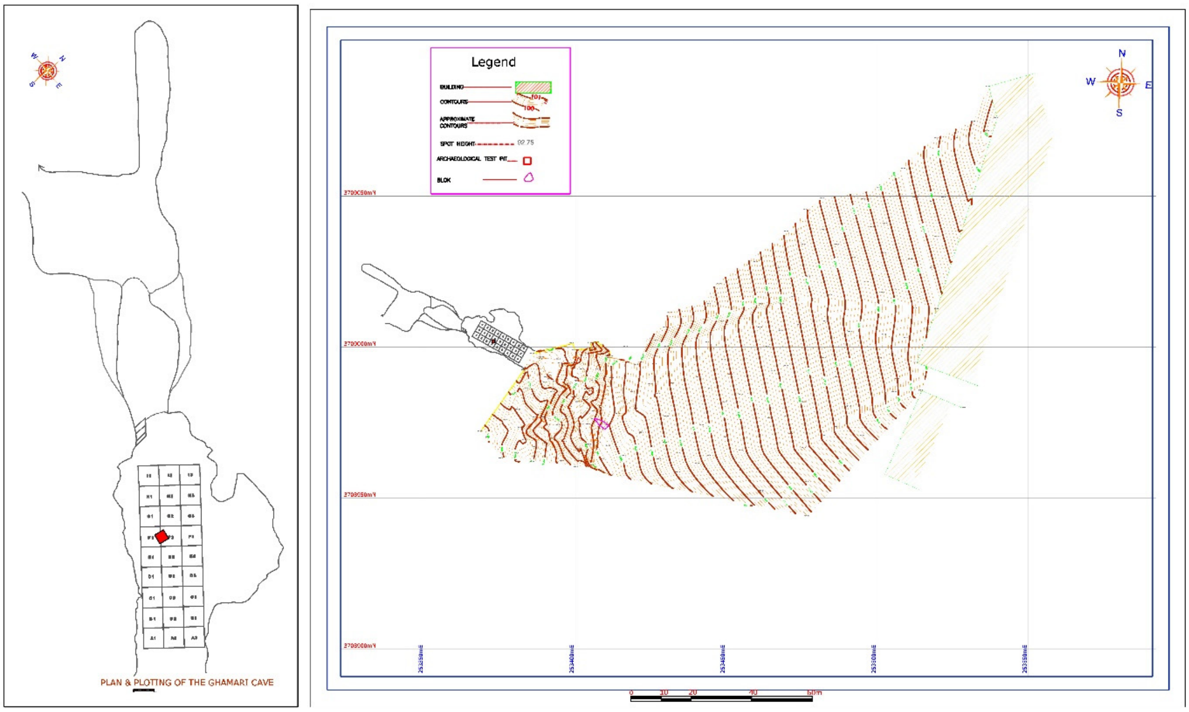


Figure 3-2B: Plotting and maping the archaeological sedimentary deposit



Detailed topography with the exact location of excavated test pit

Figure 3-2C: Topography of Ghamari Cave and its surrounding area. Location of test excavation is shown in red coulour.

3-2a: Stratigraphy and archaeological context

Besides Gilvaran Cave with its huge amount of archaeological sedimentary deposit, Ghamari Cave holds another big archaeological area. We decided to explore the sediment fill of this cave, digging a 1 ×1m test trench, located between F1&F2 grids from our mapping plot (Fig 3-2aA). But the sedimentary sequence in this locality showed up to be much ticker than what we tought earlier. We stoped our test trench because of lack of light, small space to continue the excavation as well as it's lose Holocene sediment that could fall any time while digging. So we stoped our test trench in about 2.5 meter depth (243cm). However, in our field observation we realized a great archaeological deposit in Ghamari. The site seems to be rich in preserving faunal remains as well as lithic industry. In a new visit we explored the cave sourounding areas. Perhaps due to some tectonic/geological movement, one of the cave entrance is lost. It is likely possible that the cave contains an archaeological sequence over than

30 meters deep (Carbonell personal communication). In such a scenario, Ghamari might also show lower Paleolithic sequence at its bottom of sequence. In the future perspectives I discuss more about this site.

However, a detailed information on Ghamari stratigraphy and archaeological context can be seen in Bazgir et al. 2014, presented here in chapter 3, sub-chapter 3-3e: Publication 1.

Figure 3-2aA: Test excavation at Ghamari Cave and schematic stratigraphy.

3-2b: Lithic industry

Apart from its clear Mousterian lithic assemblage from layer 5, we roughly estimated an early Upper Paleolithic technology mostly on few diagnostic elongated retouched pieces showing Baradostian technology. However, due to small excavated area as well as lack of chronometric dates, our knowledge about Middle to Upper Paleolithic transition in this site remained poorly understood. As discussed in stratigraphy and archaeological context, the nature of lower archaeological context also remain unknown to us. New field work enlarging excavation areas will certainly provide a better picture of Ghamari´s sequence and its lithic industry. The recovered lithic industry from Ghamari Cave is provided with details in Bazgir et al. 2014, presented in this thesis.

3-2c: Faunal remains

The identified taxa are presented here.

Sus scrofa

A fragment of a lower male canine of a suid has a sharp angle between the lingual and posterior sides. This is typical in "scrofic" canines. Such a section occurs in *Sus scrofa*, while other Pleistocene pigs tend to have "verrucose" canines, as in *Sus verrucosus*. In these canines the same angle approaches 90 degrees.

Cervidae indet. cf. *Cervus elaphus*

A fragment of a metatarsal indicates the presence of a cervid, the size of *Cervus elaphus*. The presence of this species has been confirmed in the nearby Kaldar Cave (Bazgir et al. 2017).

Bovini indet.

A right tooth row comprising the upper P2 to M3 has a bovine morphology. Its morphology and size would fit both *Bos* as well as *Bison*.

Caprini indet. cf. *Capra aegagrus*

Dental and postcranial material indicates the presence of a goat-like animal. Some of the specimens were figured (Bazgir et al., 2014, SOM figures 3/3, 3/5 and 3/6) and assigned to Caprini indet. cf. *Capra aegagrus*. The presence of *Capra* has been confirmed in the nearby Kaldar Cave (Bazgir et al., 2017).

Hystrix* sp. cf. *Hystrix indica

Several cervical, a thoracic and a lumbar vertebra and probably also some other bones belong to a porcupine. Bazgir et al. (2014, figure 8/8, SOM figure 4/1-2) figured the axis and compared to that of a recent *Hystrix cristata.* This is the largest species of porcupine, but the fossil was still a little large, however its morphology is not exactly the same. For this reason the material was tentatively assigned to *Hystrix indica*, which is nearly as large and lives in Iran in the present and which has been cited from the Iranian Pleistocene (Aulagnier et al., 2009; Mashkour et al., 2009).

A full description of the identified species and their contribution in the global context is presented in Bazgir et al. 2014.

3-2d: Functional Studies:

As discussed in (sub-heading 3-1e), as a part of our multidisciplinary studies, we documented the microscopic occurrence of usewear. At this point my aim was just to assess the feasibility of such studies for each sites within Khorramabad Valley and to introduce these types of analysis in Iranian Paleolithic studies. The provided samples are a limited number of cases and do not offer any functional interpretations at this point (Figs 3-2dA to 3-2dD).

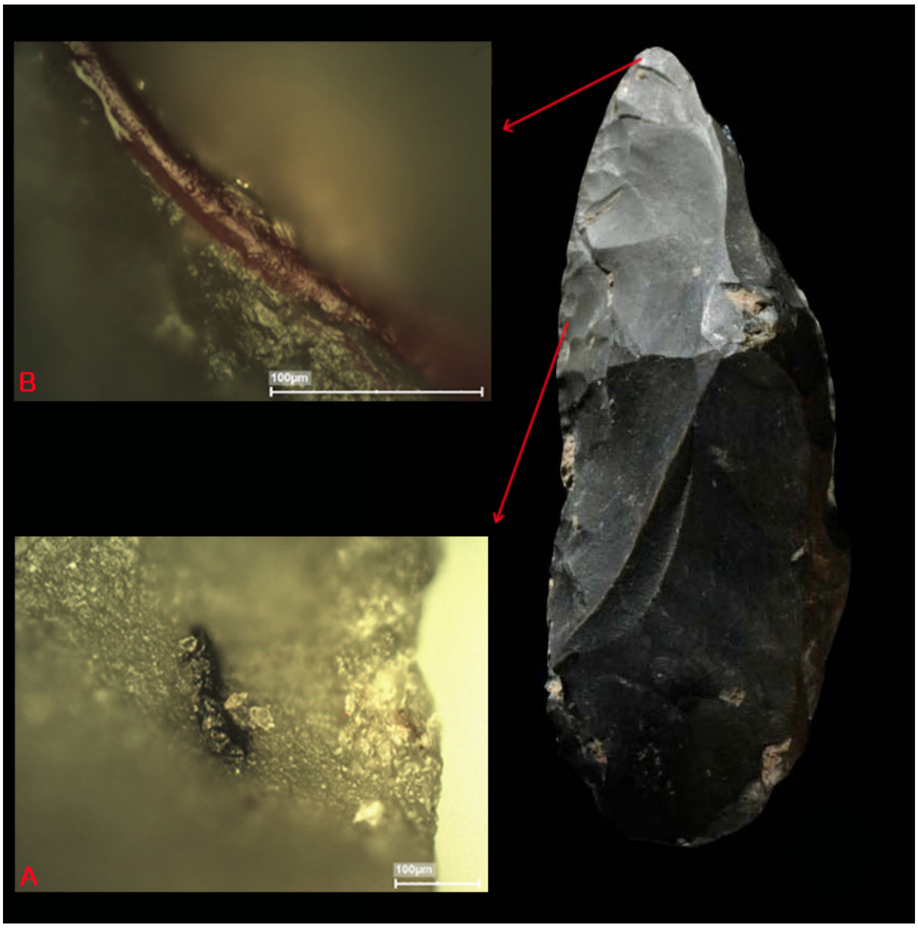


Figure 3-2dA: Microscopic residues on distal and medial part of a limace (Middle Paleolithic, layer 5).

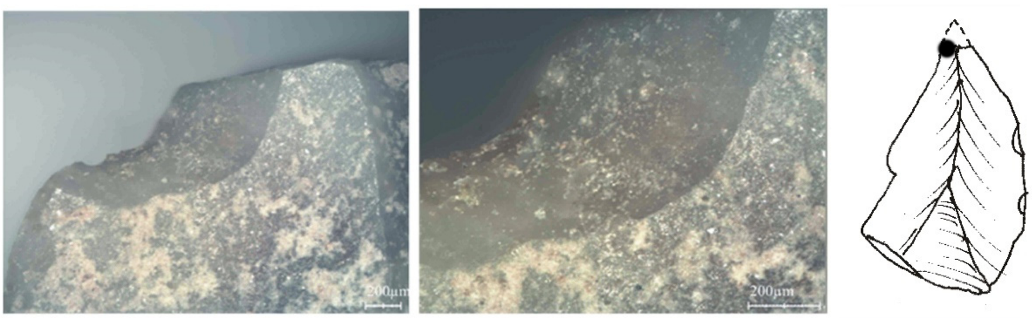


Figure 3-2dB: Macro fracture on distal part of a Levallois point (same point with different magnification) (Middle Paleolithic, layer 5).

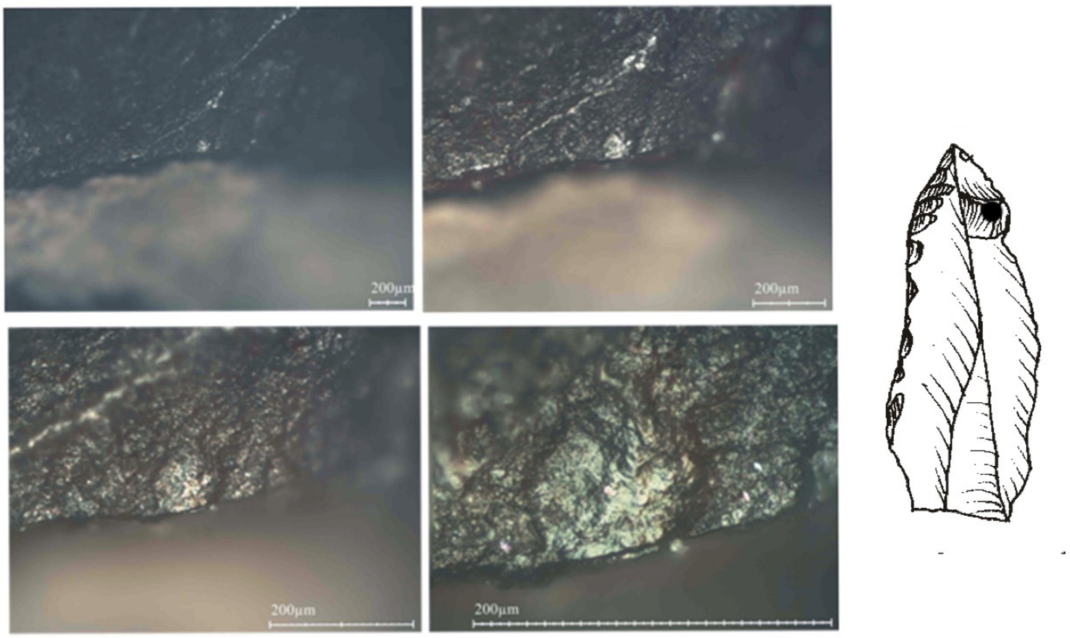


Figure 3-2dC: Polish on the distal part of a retouched Levallois point (same point from 50 to 500 mag) (Middle Paleolithic, layer 5).

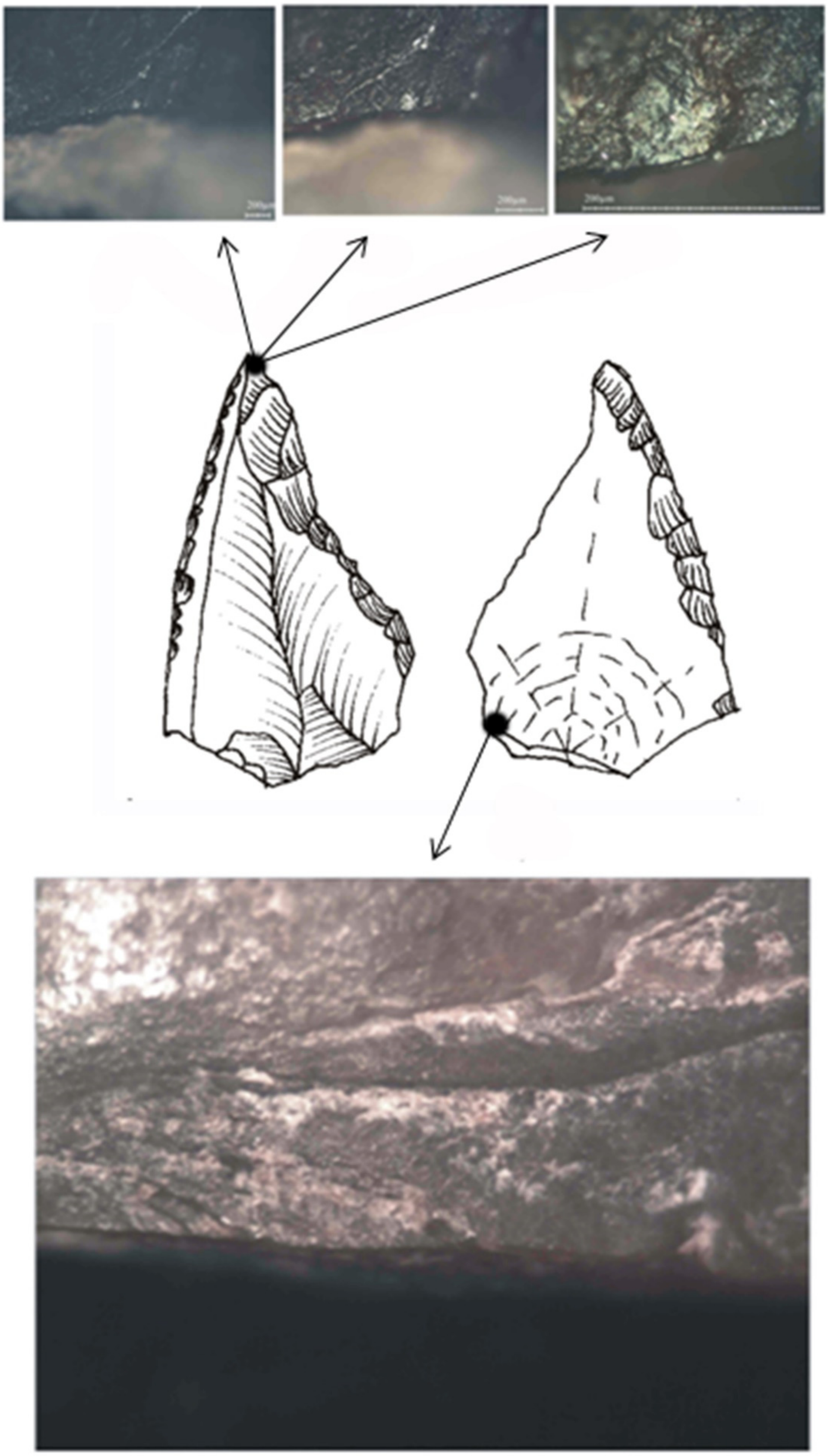
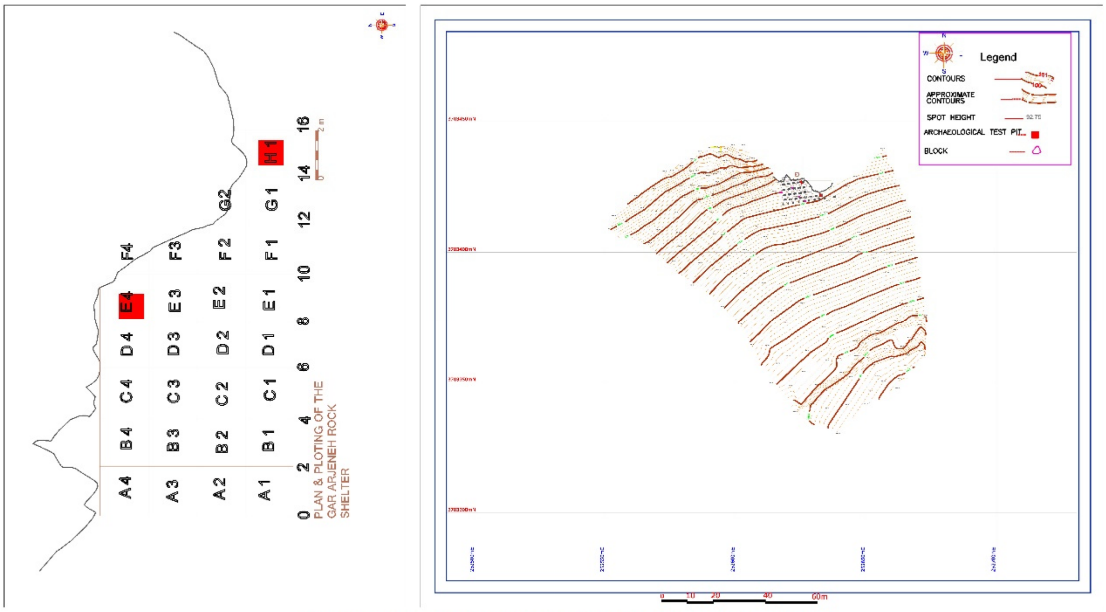


Figure 3-2dD: Polish on distal and macro fracture on proximal part of the retouched Levallois point (Middle Paleolithic, layer 5).

3-3: Excavation at Gar Arjeneh Rock Shelter

It is located in 48◦:20_:21__E longitude, 33◦:26_:30N latitude and 1205 m a.s.l. As was noted by Hole and Flannary´s excavation in 1967, the site was badly disturbed by intrusive porcupine burrows. Moreover, in their field report they did not provide the plan of the shelter with the location of the excavated trench, so, the exact location of their trench was unknown to us. Having these issues in mind, in our 2010 exploration of the site, accidentally we came across a local old man who reside in the village next to the site. Surprisingly he was one of Hole and Flannary´s workers in their 1960´s excavation. With this privilege I came to know the exact location of their trench. With these information I decided to open a new trench in other areas of the archaeological deposits with the aim to test if we can find a location with undisturbed deposit. To do so, we first maped and plotted the archaeological sedimentary of the site and then carried out its topography (Fig 3-3A). However, despite opening 2 different test pits in different areas, the deposit did not show any sign of stratigraphy (Fig 3-3B).

Figure 3-3A: Mapping and plotting the archaeological sedimentary of Gar Arjeneh rock shelter.



Detailed topography with the exact location of excavated test pits

Figure 3-3B: Topography of archaeological sediments and outskirt of Gar Arjeneh rock shelter. Location of two test pits are shown in red colour.

3-3a: Stratigraphy and archaeological context

Unfortunately both the test pits did not show clear stratigraphic sequence. The deposit in this site has been badly disturbed by porcupine burrows as well as modern activities by villagers living next to the site. In our excavation, all the recovered lithic industries and faunal remains were recorded by depth and coordination's, but due to absence of a clear stratigraphy with several burrows and recent materials, we were able only to categorize the lithic industry based on their typological features. However, despite all these problematic issues with this site, it is interesting that there are presence of diagnostic tools with general characteristics of both Mousterian and Baradostian. However, in case of Gar Arjeneh, further field work is needed. Finding locations with proper stratigraphy might provide better information about its cultural sequences.

3-3b: Lithic industry

Although based on stratigraphic position assessing the recovered lithic assemblage from Gar Arjeneh is impossible, however, following our typological categorization the assemblage is dominated mostly by retouched side scrapers showing Levallois technique as well as several diagnostic retouched bladelets similar to Baradostian technology. Further field work is needed to recover lithics in situ to be able to understand the chronology of the site and its possible transition from Middle to Upper Paleolithic.

3-3c: Fanunal remains

***Capreolus* sp.**

The proximal epiphysis of a first phalanx has the morphology of a small bovid or cervid. It was figured and described and best fits *Capreolus* (Bazgir et al., 2014, SOM figure 1/2).

Mammalia indet.

A fragment of a coprolite with a cylindrical shape, has a diameter of 30 to 33 mm and a length of 64 mm. A grove spirals along its surface, suggesting that this reflects an internal structure. The specimen has more or less the diameter of hyena coprolites, but does not consist of two or three pellets, as could be the case in a hyena coprolite.

3-3d: Functional studies

Due to serious stratigraphic problem in this site, except for a typological categorization of the lithic industry from this site, we did not perform any studies on the findings in this site.

3-3e: Publication 1

Behrouz Bazgir, Marcel Otte, Laxmi Tumung, Andreu Ollé, Sushama G. Deo, Pramod Joglekar, Juan Manuel López-García, Andrea Picin, Davoud Davoudi, Jan van der Made. 2014. Test excavations and initial results at the Middle and Upper Paleolithic sites of Gilvaran, Kaldar, Ghamari caves and Gar Arjene Rockshelter, Khorramabad Valley, western Iran. Comptes Rendus Palevol. Vol.13. pp 511-525.

This publication deals with the initial results of our test excavations at Gilvaran, Kaldar, Ghamari caves and Gar arjeneh rock shelter. Each site stratigraphy, cultural evidences and preliminary results are presented.

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Test excavations and initial results at the Middle and Upper Paleolithic sites of Gilvaran, Kaldar, Ghamari caves and Gar Arjene Rockshelter, Khorramabad Valley, western Iran

Sondages et premiers résultats acquis sur les sites paléolithiques de la vallée de Khorramabad, Iran occidental : Gilvaran, Kaldar, Ghamari, Gar Arjeneh

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ABSTRACT

This paper introduces the excavations in several Paleolithic sites in the Khorramabad Valley, Western Iran. Apart from the two well-known sites of Ghamari Cave and Gar Arjene rock shelter, first excavated by Frank Hole and Kent Flannery in the 1960s, the Gilvaran and Kaldar caves were excavated for the first time. Here we present the stratigraphy of these sites, general data from the lithic assemblages, and the identifications of a small part of the faunal remains. Preliminary results are showing that all of the sites were occupied from the Middle and Upper Paleolithic onward, and therefore provide great potential for the study of the transition between these cultural periods. Our preliminary techno-typological observations show that the lower levels of the Gilvaran and Ghamari sequences may represent an early phase of the Middle Paleolithic.

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R É S U M É

Ce texte résume les résultats de fouilles paléolithiques menées par une équipe internationale dans différents sites de la vallée de Khorramabad, en Iran occidental. Les sites de Ghamari et Arjeneh ont, à l'origine, été fouillés par Frank Hole et Kent Flannery dans les années 1960. Ceux de Gilvaran et Kaldar ont été explorés pour la première fois par notre équipe. Nous présentons la stratigraphie ainsi que des données générales et les résultats quantitatifs obtenus pour l'essentiel des composantes lithiques ; l'identification préliminaire de la faune est aussi fournie. Ces résultats provisoires montrent que tous ces sites ont été occupés durant le Paléolithique moyen et supérieur. Ils fournissent ainsi un puissant potentiel pour l'analyse des processus de transition entre ces phases culturelles. Des échantillons ont été prélevés aux différents sites, afin d'y établir une séquence chronologique. Les études techniques et typologiques montrent que les phases anciennes de Gilvaran et de Ghamari appartiennent au Paléolithique moyen.

Mots clés :
Paléolithique moyen
Paléolithique supérieur
Grottes de Gilvaran
Kaldar et Ghamari
Abri d'Arjeneh
Vallée de Khorramabad
Iran occidental

1. Introduction

Recent research in paleoanthropology underscores the importance of Southwest Asia for the evolution of hominins and their dispersal to other regions (Hughes et al., 2007; Martinón-Torres et al., 2007). Its geographic position as a crossroad between Africa, Europe and eastern Asia plays a strategic role in the understanding of the biological developments of different human lineages and of the spread of different knapping technologies (Bermúdez de Castro and Martinón-Torres, 2013). Consequently, SW Asia, including Iran, certainly played an important role in Paleolithic cultural development. However, the patchy distribution of archaeological evidence and the diverse local research traditions entail some differences within these territories. The Zagros Mountains are a key area to disentangle the events that mostly marked the archaeological record of the Late Pleistocene.

The spread of techno-complexes of blades/bladelets associated with Anatomically Modern Humans across Eurasia is documented at 45–40 kyr before present (Goring-Morris and Belfer-Cohen, 2003; Mellars, 2006). This technological innovation was accompanied by other cultural novelties such as portable art, graphic representations, musical instruments and bone projectiles (Bar-Yosef and Zilhão, 2006; Conard, 2003; Conard et al., 2009). In the same chronological interval, Neanderthals, who lived in an area that extended from the Iberian Peninsula to Siberia, suddenly disappeared. Several hypotheses have been advanced but the causes that led to the Neanderthal extinction are still debated (Lowe et al., 2012; Tzedakis et al., 2007; Valet and Valladas, 2010; Wolff and Greenwood, 2010). In this scenario, tracing where these blade/bladelets industries developed is crucial to figure out the patterns of dispersal of Anatomically Modern Humans, the possible interaction with Neanderthals and the causes of their disappearance.

In the central Zagros, several sites document the presence of blade/bladelet assemblages, the oldest one named Baradostian (Garrod, 1937) and a younger one indicated as Zagros Aurignacian (Olszewski and Dibble, 1994, 2006). Some stone tools (Gar Arjeneh points, rectilinear and curved bladelets with inverse retouch) were found in these lithic assemblages, that resemble elements of the typical toolkits of the European Proto-Aurignacian and Aurignacian such as Font-Yves and Krems points, and Dufour bladelets (Tsanova, 2013). Few dates are available for these sites but the recent radiocarbon dating of charcoals from Yafte Cave (Iran) reveals that the Baradostian levels predate the chronological range of the Levantine Aurignacian, predate and overlap with some Early Ahmarian dates, and are contemporaneous with assemblages of the northern Caucasus (Otte et al., 2011). These results place the Iranian Late Paleolithic in an intermediate chronological position between the Levant Ahmarian and the Kozarnikien (Tsanova et al., 2012), suggesting its possible role as a source for the development of the Aurignacian culture (Otte and Kozłowski, 2004; Otte et al., 2012).

The Khorammabad Valley is a narrow passage connecting the northern highlands with the southern lowlands of Khuzistan and constitutes one of the important passageways for both humans and animals to cross the Zagros mountain range. The presence of numerous caves and rock shelters, springs and rivers and the Pleistocene paleoenvironment seem to have been favorable for human settlement in the area. As a consequence, the Khorramabad Valley likely played a significant role in human adaptation and dispersal during the Quaternary. However, there are only a few studies that deal with the sites in this area (Baumler and Speth, 1993; Field, 1951a, 1951b; Hole and Flannery, 1967; Otte and Kozlowski, 2007; Otte et al., 2007, 2011; Roustaei et al., 2002, 2004; Shidrang, 2007; Speth, 1971; Tsanova, 2013; as well as a reassessment paper on the Hole and Flannery report: Vahdati Nasab, 2010).

In this paper we are presenting preliminary results of the archaeological excavations at four Paleolithic sites in the Khorramabad Valley (Western Iran) (Fig. 1) of which the well-known sites of Ghamari cave and Gar Arjeneh rock shelter were excavated after Hole and Flannery's excavation in 1960s, while the Gilvaran and Kaldar caves were excavated for the first time. In all these sites, Middle and Upper Paleolithic human occupations were documented, adding new data to this important period of human evolution.

A general summary of the findings in the 4 excavated sites (Table 1), and detailed quantification results of the

Table 1
Summary of the archaeological materials recovered in the 2011–2012 seasons at the Khorramabad Valley sites.
Tableau 1
Résumé du matériel archéologique découvert en 2011–2012.

Site	Lithic remains	Faunal remains
Gilvaran (GLV-AY1)	5391	2740
Gilvaran (GLV-A8)	1818	871
Kaldar (KLD)	1394	1296
Ghamari (GHM)	1106	1475
Gar Arjeneh (GRA)	566	698
Total	**10,275**	**7080**

levels attributed to Middle and Upper Paleolithic in 3 of these localities are shown in the Tables 2 and 3. The results comprise two sections. The first section presents the four sites, making special reference to the main stratigraphic issues and to the lithic assemblages. The second is dedicated to the paleontology: it gives detailed descriptions in the Supplementary Online Materials (SOM), gives the faunal lists and briefly discusses some biogeographic aspects.

2. The archaeological sites

2.1. Gilvaran Cave

The cave is situated in the northwestern part of the Khorramabad Valley and located in 48°:18′:56″E longitude, 32°:28′:12″N latitude, and about 1225 m a.s.l (SOM Fig. 1A and E). It is 16 m long, 17 m wide and 7 m high. In 2002, the cave was officially included with record number 5971 into the Lorestan Cultural Heritage, Handicraft and Tourism Organization (LCHTO) archive as an Upper Paleolithic site by A. Parviz. The site has been visited twice; by an Iranian team in 2002 and by international team in 2004, both lead by K. Roustaei. They have systematically carried out surface collection on this locality. "Twenty-one collections ranging in size from a single artifact (Dozaleh II rock shelter, region 3) to 357 pieces (Gilvaran I, region 1) were recovered" (Roustaei et al., 2004, p. 7).

We explored the sediment fill of this cave with two test-pits of 2 × 2 m named AY1 and A8. AY1 is situated at the southern side of the cave opening at about 20 m

Table 2
Quantification results of the lithics attributed to Middle Paleolithic levels of the three excavated sites in the 2011–2012 seasons at the Khorramabad Valley.
Tableau 2
Résultats de la quantification des industries lithiques des trois sites fouillés au cours des années 2011–2012 dans la vallée de Khorramabad, attribués aux niveaux du Paléolithique moyen.

	GLV-AY1-Level 5		GLV-A8-Level 3		KLD-Level 5		GHM-Level 5	
	n	%	*n*	%	*n*	%	*n*	%
Cortical piece	101	*4.0*	162	*11.3*	6	*5*	27	*12.1*
Levallois flake	66	*2.6*	66	*4.6*	8	*6.6*	28	*12.5*
Levallois blade	11	*0.4*	12	*0.8*	4	*3.3*	4	*1.8*
Levallois point	48	*1.9*	15	*1.1*	9	*7.4*	16	*7.1*
Levallois core	7	*0.3*	7	*0.5*	1	*0.8*	–	–
Other types of core	4	*0.2*	1	*0.0*	3	*2.5*	–	–
Retouched tool	227	*9*	119	*8.3*	42	*34.7*	68	*30.4*
Flake byproducts	1894	*75.1*	N/A	*N/A*	16	*13.2*	63	*28.1*
Debris	149	*5.9*	211	*14.7*	31	*25.7*	18	*8*
Hammerstone	14	*0.6*	9	*0.6*	1	*0.8*	–	–
Total	2521	*100*	1428	*N/A*	121	*100*	224	*100*

Due to the hybridity caused by fallen rocks in level 3 of A8 trench of Gilvaran, distinguishing Levallois and blade byproducts was not possible, therefore in this case and in this trench, we presented exceptionally the same total numbers for the GLV-A8-Level 3 in the Tables 2 and 3. The sign "N/A" here means "data not applicable".
The total numbers given for "Retouched tool" in the Tables 2 and 3 for all the sites excluded other retouched tools such as retouched Levallois points, Levallois flakes, etc.

Table 3
Quantification results of the lithics attributed to Upper Paleolithic levels of three of the excavated sites in the 2011–2012 seasons at the Khorramabad Valley.
Tableau 3
Résultats de la quantification des industries lithiques des trois sites fouillés au cours des années 2011–2012 dans la vallée de Khorramabad, attribués aux niveaux du Paléolithique supérieur.

	GLV-AY1-Level 4		GLV-A8-Level 3		KLD-Level 4		GHM-Level 4	
	n	%	*n*	%	*n*	%	*n*	%
Cortical piece	43	*3.8*	–	–	2	*0.3*	6	*4.2*
Blade	196	*17.5*	88	*6.2*	92	*16.4*	27	*18.9*
Bladelet	180	*16.0*	73	*5.1*	89	*15.8*	17	*11.9*
Blade core	7	*0.6*	3	*0.2*	1	*0.2*	–	–
Bladelet core	3	*0.3*	1	*0.1*	1	*0.2*	–	–
Retouched tools	146	*13*	–	–	11	*1.9*	33	*23.1*
Other type of core	2	*0.2*	–	–	1	*0.2*	–	–
Blade byproducts	365	*32.6*	N/A	*N/A*	312	*55.6*	46	*32.1*
Debris	179	*16.0*	–	–	53	*9.4*	14	*9.8*
Hammerstone	–	–	–	–	–	–	–	–
Total	1121	*100*	1428	*N/A*	562	*100*	143	*100*

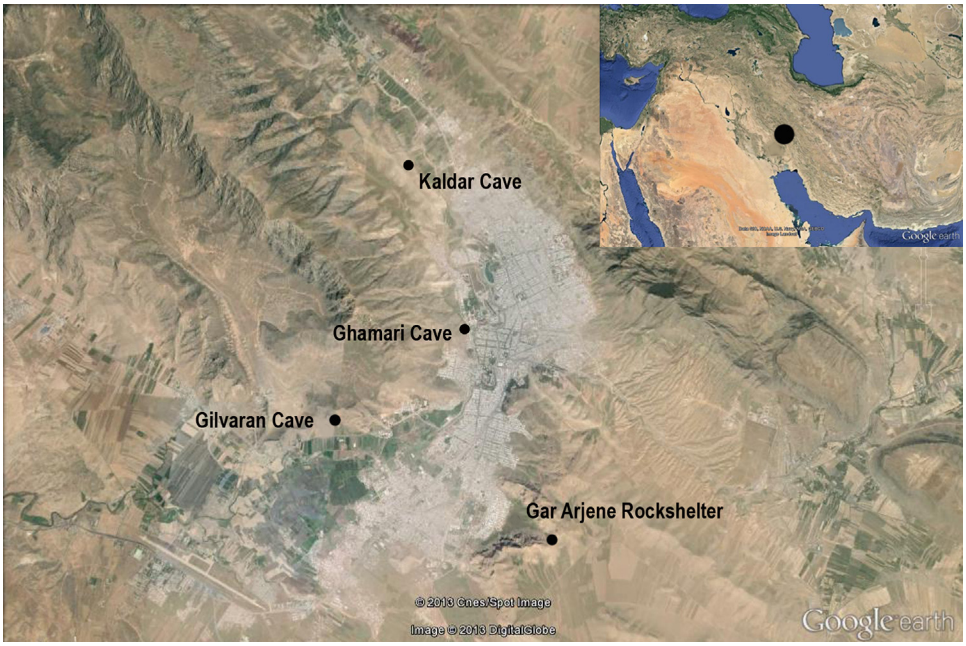

Fig. 1. (Color online). The geographic position of the Khorramabad Valley and the position of the localities indicated on an aerial photograph.
Fig. 1. (Couleur en ligne). Position géographique de la vallée de Khorramabad et localités indiquées sur la photo aérienne.

from the drip line (SOM Fig. 1 D). A8 was dug again at the southern side of the cave opening at about 4 m from the drip line (SOM Fig. 1B). Samples for contextual studies, including sedimentology paleontology paleoenvironment (pollen, charcoal, seeds, and land snails) and dating (OSL tubes and charcoal) were systematically collected (Fig. 2).

Test-pit AY1 exposed a 4.8 m section of the sedimentary deposit and is characterized by 5 main levels (Fig. 3B). Level 1 consists of ashy sediment with a blackish green color with angular stones. It has a thickness that varies from 5 to 20 cm. This is the most recent level and it contains an assemblage of Islamic materials. Level 2 consists of sediment with a fine light gray color and with few angular stones. It varies in thickness from 28 to 84 cm and it includes a Historical and Bronze Age record. Level 3 consists of grey coarse sandy sediment, that varies from 60 to 110 cm in thickness and which has mixed Chalcolithic and Neolithic potsherds and lithic industries. Level 4 consists of dark gray sediment with a large number of limestone blocks of different sizes and varies from 39 to 62 cm in thickness. It contains an Upper Paleolithic assemblage. Level 5 is a reddish brown deposit with many large limestone blocks. It increases in depth from the northern towards the southern section, varying from 2.45 to 2.85 m in thickness. It includes two sub-levels that have no difference in color. Middle Paleolithic industry is found in sub-level 1, and mixed Middle and early Upper Paleolithic/Baradostian industries in sub-level 2 (Fig. 4A1 and A2 and SOM Fig. A1 and A2).

Test-pit A8 showed a sequence of 1.5 m of sedimentary deposit, in which three levels could be recognized, (Fig. 3A) and overlying a layer of heavy rocks, deposited due to the collapse of the entry of the cave (SOM Fig. 1C). Level 1 consists of ashy blackish green sediments with a

Fig. 2. (Color online). Collection of sediment samples at Gilvaran Cave.
Fig. 2. (Couleur en ligne). Récoltes d'échantillons sédimentaires à Gilvaran.

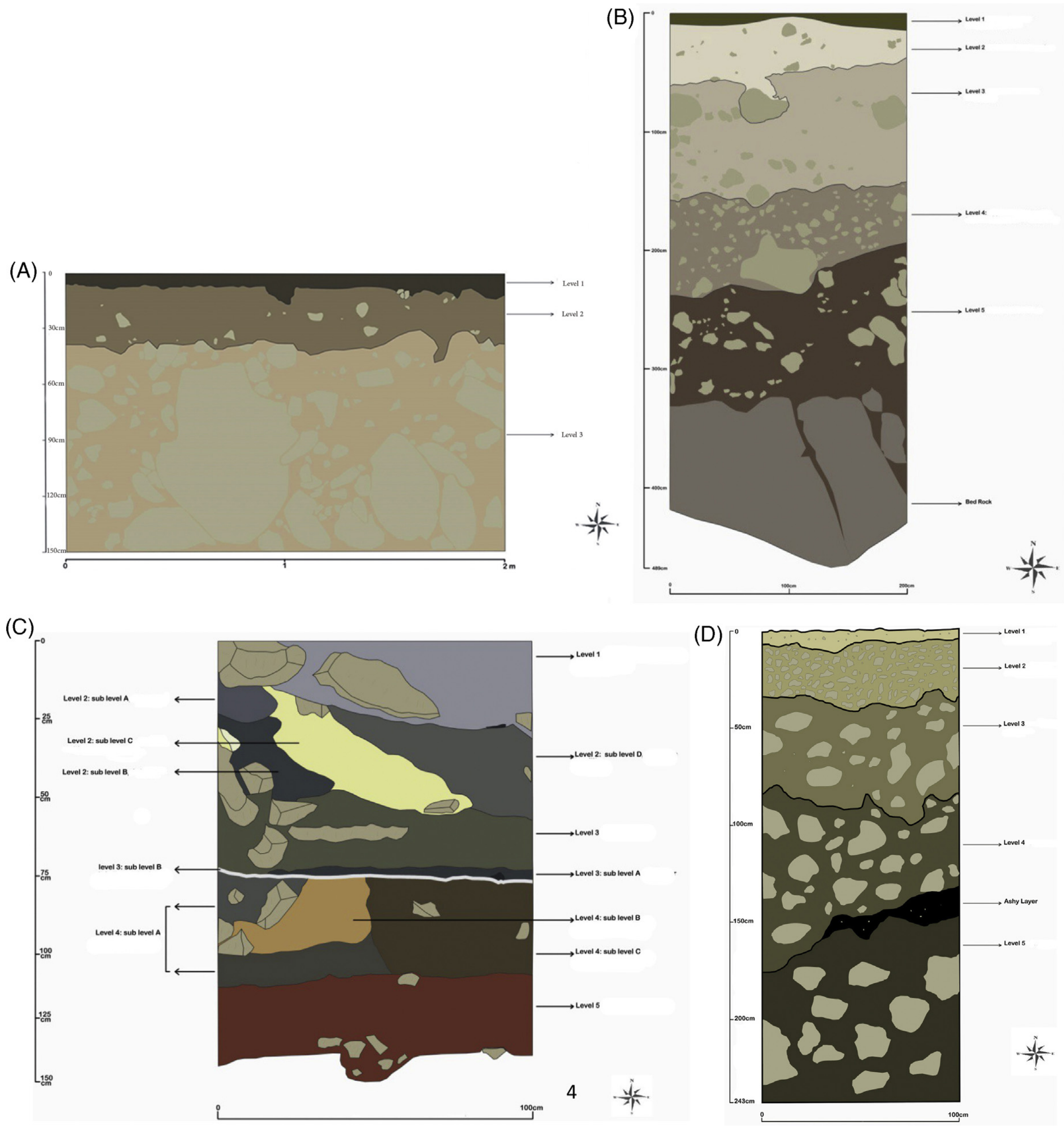

Fig. 3. (Color online). A. Gilvaran = Stratigraphy of the northern section of trench A8. B. Stratigraphy of the northern section of trench AY1. C. Kaldar = northern section of the D4 test-pit and detailed stratigraphy. D. Ghamari = the F2 (detailed stratigraphy).
Fig. 3. (Couleur en ligne). A. Gilvaran = Stratigraphie du côté nord de la tranchée A8. B. Stratigraphie du côté nord de la tranchée AY1. C. Kaldar = section nord du sondage D4 et stratigraphie détaillée. D. Ghamari = sondage F2, stratigraphie détaillée.

thickness varying from 5 to 10 cm and includes a superficial layer with Historical and Islamic materials. Level 2 consists of dark gray sediment with a few limestone blocks and has a thickness from 19 to 30 cm. It includes a unit of mixed Neolithic, Chalcolithic and Bronze Age. Level 3 consists of light gray sediment with a large number of angular limestone blocks and has a thickness from 31 to 150 cm. It contains a unit of mixed Middle and Upper Paleolithic (SOM Fig. 6A1 and A2).

The important assemblage of Mousterian industry from level 5 stands out in this sequence. In the lower part of sub-level 1 in level 5, a variety of Mousterian points and flakes, made with Levallois technique is present in large numbers. By contrast, in sub-level 2, we have observed both the Middle and Early Upper Paleolithic/Baradostian industry that seems to be mixed due to the variation in the depths. The most common retouched tool types in this level are different kind of points, side-scrapers, déjeté

(A1)


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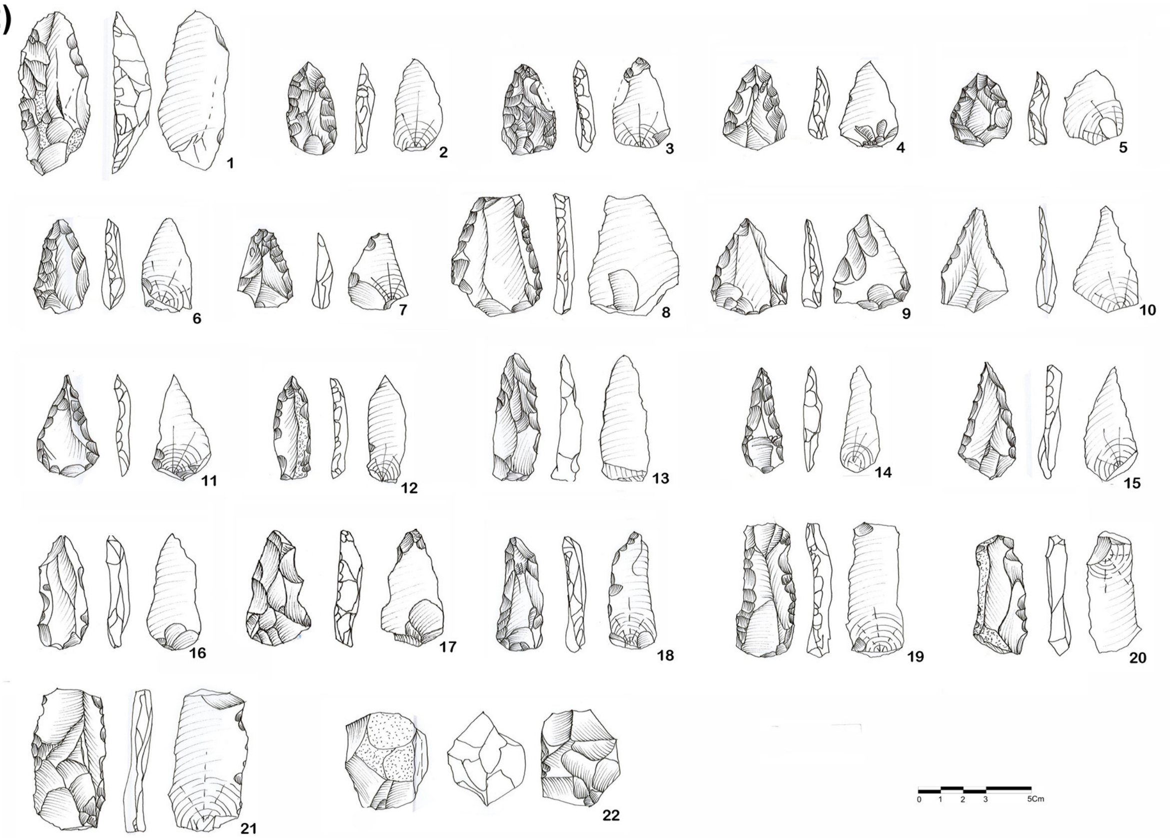
(A2)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scrapers, double-scrapers and other tools that do not fit to any known standard (some of them fractured).

Among the points, a wide variety of types has been identified, including Levallois points, Mousterian, limaces and Tayac points, unmodified and asymmetrical pointed flakes, resulting from unidirectional reduction, with different kinds of platform preparations (retouched, flat, dihedral, faceted, cortical). This variety makes Gilvaran somewhat different from the other localities in the Khorramabad Valley. The side-scrapers are mostly produced on core-edge flakes.

In the AY1 and A8 trenches, we recovered a total of 23 hammer stones showing discrete patches of pitting and crushing, reflecting that hard hammer percussion took place on the site (SOM Fig. 7). The principal knapping methods identified are Levallois recurrent centripetal and discoid as described by (Boëda, 1993, 1994). Retouched artifacts in the Upper Paleolithic industry in both AY1 (level 4) and A8 (level 3) are dominated by different types of flakes, blades and bladelets.

At the bottom of the Upper Paleolithic levels of both the trenches, tools are found that show some general characteristics of early Upper Paleolithic/Baradostian industry, such as long blades and bladelets, side-scrapers, end-scrapers (mostly fractured) and composite/multifunctional tools with step retouches, different types of pointed flakes along with bladelet cores. Unfortunately, in this level most of the cores are covered with heavy concretion.

As a consequence, in level 5 of Gilvaran cave, two distinct sub-levels have been recognized. The lower one contains many elongated flakes, produced by hard hammer on facetted platform, which subsequently were retouched or pointed. The upper sub-level contains elongated blades obtained with soft hammer, very clearly made with an Upper Paleolithic technology. These blades have been transformed into burins, scrapers with bilateral retouches. Some points made on bladelets are the so-called "Arjeneh" type. Also one carenated scraper was recovered. The upper part of the level 5 belongs to the Zagros Aurignacian, as it has been found in Yafteh and in many other sites in Iran (Otte and Kozlowski, 2007).

Hence, Gilvaran Cave is a promising site located in a suitable part of Khorramabad Valley, in particular for the study of technological variability and its potentiality for Middle to the early Upper Paleolithic transition.

2.2. Kaldar Cave

This cave is situated north of Khorramabad valley at 48°:17′:35″E longitude, 33°:33°:25N latitude and 1290 meters a.s.l (SOM Fig. 2 A, B and C). It is 16 m long, 17 m wide and 7 m high. In 2007, Z. Bakhtiari realized the archaeological importance of this cave. He recorded it with the file number 18796 in the LCHTO archive as an Epipaleolithic site. This site is located in the "Wild Life Century" zone, where it is protected from illegal excavation, which is a common problem in almost all Khorramabad localities. However, the cultural deposit in this case is very well preserved.

The fill of the cave was investigated with a test-pit of $1 \times 1\,m^2$ at the center inside the cave very close to the drip and reveals in 1.5 m a stratigraphic succession of five levels and six sub-levels (Fig. 3C). Level 1 consists of fine light gray sediment with large angular limestone blocks. This level has a thickness varying from 12 to 28 cm and it contains mixed Islamic, Historical and Chalcolithic materials. Level 2 consists of 4 sub-levels varying from colors (white, gray, bluish gray and dark bluish gray) with several angular blocks and a thickness from 37 to 42 cm. The cultural remains in this level includes: Sub-level A and B ashy layer, sub-level C Neolithic with typical potteries, sub-level D Pre-pottery Neolithic. Level 3: Contain three sub-levels resulting from fire activities with some flat and irregular limestone blocks with a thick ashy color and very thin bluish gray and lime color and soft sediment varying in a thickness from 19 to 24 cm with presence of different fractured flints showing Epipaleolithic characteristics.

Level 4 consists of 3 sub-levels in dark brown, cream and bluish gray tense sediments, angular blocks. Its thickness varies from 30 to 35 cm. Its archaeological content shows Upper Paleolithic features. Level 5 consists of hard sandy reddish brown sediment with few small irregular blocks and has a thickness that varies from 30 to 35 cm. It contains a Middle Paleolithic assemblage, but at the top some blade technology appears, which might correspond to an early Upper Paleolithic phase.

Fig. 4. (Color on line). A1 and A2. Selected artifacts from Gilvaran GLV-AY1 trench, level 5 and 4: (same as picture above). 1: Limace, 2: Mousterian point with retouched platform, 3: Mousterian point with retouched platform and a fracture on its distal portion, 4: Mousterian point on Levallois flake with two convergent negatives and faceted platform, 5: déjeté scraper or Mousterian point, 6: Mousterian point with dihedral platform, 7: fragmented Mousterian point on Levallois flake, 8: point with direct flat retouches on the left side and three inverse notches on the right side, 9: Levallois point, concretion covers the platform, 10: déjeté scraper, 11: elongated Mousterian point with cortical platform, 12: elongated Mousterian point with flat platform, 13: elongated Mousterian point with dihedral platform, 14: déjeté scraper, 15: Mousterian point with retouched platform, 16 and 17: Tayac points, 18: double scraper on Levallois recurrent unidirectional blank, 19: déjeté scraper, 20: side-scraper with cortical platform on semi-cortical natural core-edge flake, 21: Levallois recurrent unidirectional blade with flat platform and pseudo-retouches on both sides, 22: polyhedral core.

Fig. 4. (Couleur en ligne). A1 et A2. Artefacts sélectionnés de la tranchée de Gilvaran GLV-AY1, niveau 5 et 4 (les mêmes que sur la planche précédente). 1 : « Limace », 2 : pointe moustérienne avec talon retouché, 3 : pointe moustérienne avec talon retouché et partie distale fracturée, 4 : pointe moustérienne sur éclat Levallois avec deux négatifs convergents et talon facetté, 5 : racloir déjeté ou pointe moustérienne, 6 : pointe moustérienne avec talon dièdre, 7 : fragment de pointe moustérienne sur éclat Levallois, 8 : pointe avec retouches plates directes latérales et reprise inverse, 9 : pointe Levallois, talon concrétionné, 10 : racloir déjeté, 11 : pointe moustérienne allongée avec talon cortical, 12 : pointe moustérienne allongée avec talon lisse, 13 : pointe moustérienne allongée avec talon dièdre, 14 : racloir déjeté, 15 : pointe moustérienne avec plateforme retouchée, 16 et 17 : pointes de Tayac, 18 : racloir double sur éclat Levallois, 19: déjeté *scraper*, 20 : racloir latéral avec talon cortical, 21 : lame Levallois à talon lisse et pseudo-retouches sur les deux bords, 22 : nucléus polyédrique.

Drawings by Laxmi Tumung.


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As in Gilvaran Cave, tools were made from different kinds of pebbles, easily available from the Robat River, which is very close to the site. In level 5, there are different types of points (mostly Mousterian and Levallois) along with pointed blades (with early Upper Paleolithic characteristics) and pointed flakes are the dominant tools, followed by side-scrapers. In level 4, flakes, blades and bladelets, polyhedral and bladelet cores along with twisted bladelets are present. As mentioned above, it was believed that the site was occupied only during the Epipaleolithic. However, the recovery in our excavation in levels 4 and 5 of many Mousterian and Upper Paleolithic tools such as points (Fig. 5A1 and A2), side- scrapers and many retouched flakes, indicates that the site was also occupied in Upper and Middle Paleolithic times.

Like Gilvaran, Kaldar Cave also is a promising site for studying the possible transition from the Middle to the early Upper Paleolithic.

2.3. Ghamari Cave

This site is located in 48°:20′:56″E longitude, 33°:29°:31N latitude and 1305 m a.s.l (SOM Fig. 3A to 3C). The fill of the cave was explored with a test-pit $1 \times 1\,m^2$ and five levels were recognized in the 2.45 m of sedimentary sequence (Fig. 3D). Level 1 consists of superficial fine cream-colored sediment with a few Islamic potsherds and a thickness varying from 4 to 9 cm. Level 2 consists of yellowish grey sediment, containing a large number of historical and Bronze Age potsherds and has a thickness varying from 25 to 40 cm. Level 3 consists of a soft and light grey color sediment with limestone blocks of different sizes varying from 45 to 70 cm and a mixed Chalcolithic and Neolithic assemblage with a few flint remains. Level 4 consists of sandy sediment with mixed grey ashy and lime color in the upper part and a black color in the lower part, which clearly results from fire activities. This level contains several limestone blocks of different sizes and is covered by concretions with a kind of heavy lime color. It contains Upper Paleolithic industry, and has a thickness from 50 to 85 cm. Level 5 consists of dark grey sediment with several large and heavy limestone blocks. It has a thickness varying from 60 to 94 cm and contains a Middle Paleolithic assemblage.

The excavation did not reach to the bedrock due to difficulties of the lighting system and high elevation. The real extent of the sedimentary sequence will be investigated in the next field work. A large number of faunal remains and some lithics were recovered from the test-pit. As a consequence, we recovered only a small number of lithics. These have the general characteristics of Upper Paleolithic industry. The Middle Paleolithic industry from level 5 stands out notably in this sequence, especially for the presence of Levallois byproducts, *limace* points and side-scrapers (Fig. 6A1 and A2). The low number of cores in Ghamari Cave could be related to the position of the test-pit further inside the cave or due to the small part investigated. In level 4, fractured retouched and not modified blades, pointed flakes, and side-scrapers are present, as well as byproducts of flaking sequences.

2.4. Gar Arjeneh Rock Shelter

It is located in 48°:20′:21″E longitude, 33°:26′:30N latitude and 1205 m a.s.l (SOM Fig. 4 A, B and C). The locality was excavated by Hole and Flannery in 1967 with some problems for tracking the stratigraphy because the deposit was too disturbed. Their notes indicate that the deposit had been badly disturbed by intrusive porcupine burrows and tools were cataloged by type and not by stratigraphic level (Petraglia and Potts, 2004). Although two 1×1 m test-pits were opened in different parts of the site, the deposit shows stratigraphic problems and no clear evidences for cultural interpretations.

Despite these problems, the analysis of the lithic assemblage documented high percentages of side-scrapers and retouched bladelets (Fig. 7A1 and A2), rather than the known Arjeneh points which certainly reflect the high degradation of the deposit. Further fieldwork is needed to give more information about the cultural sequences and the stratigraphy.

3. Paleontology

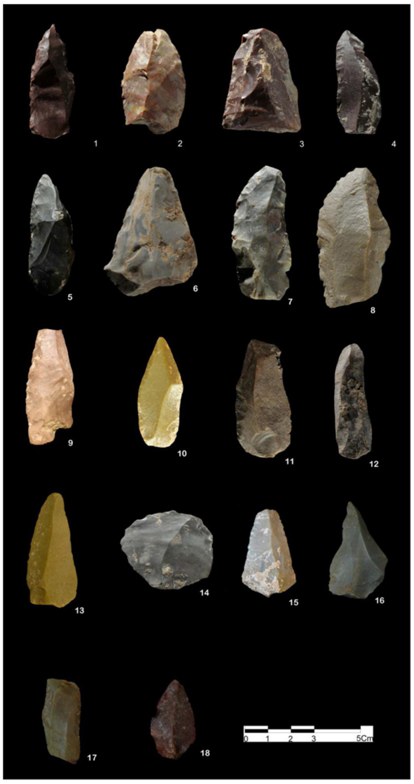
A small collection of the fossils from the excavations in the Khorramabad Valley was taken to Tarragona and has been studied in detail. Some of these specimens are illustrated in Fig. 8. Detailed descriptions, comparisons and taxonomic discussions are given as Supplementary Online Materials. The list of identified animal species is given below:

Crustacea indet.: Kaldar Cave
Erinaceidae indet.: Ghamari Cave
Chiroptera indet.: Ghamari Cave
Leporidae? indet.: Kaldar Cave

Fig. 5. (Color on line). A1 and A2. Selected artifacts from Kaldar KLD level 5 and 4. 1: Distal portion of a fragmented Mousterian point on a Levallois blank, 2: point on a Levallois flake with dihedral platform, 3: Levallois point with flat platform, recurrent unidirectional convergent, 4: side-scraper on cortical blade with faceted platform and unidirectional convergent negatives, 5: predetermining Levallois flake with four convergent negatives, flat platform, 6: Levallois point on core-edge flake with flat platform, 7: semi-cortical flake with flat platform and presence of unidirectional negatives, 8: Levallois point with dihedral platform obtained by the recurrent unidirectional modality, 9: pointed flake on Levallois core, 10: twisted bladelet with flat platform, 11: flake of re-shaping the knapping surface, 12: bladelet core, 13: fragmented bladelet core with four negatives.

Fig. 5. (Couleur en ligne). A1 et A2. Sélection d'artefacts de la grotte KLD, niveau 5 et 4. 1 : partie distale d'une pointe moustérienne sur éclat Levallois, 2 : pointe sur éclat Levallois à talon dièdre, 3 : pointe Levallois à talon lisse, récurrent unidirectionnel convergent, 4 : racloir sur lame corticale avec talon facetté et négatifs unidirectionnels convergents, 5 : éclat Levallois prédéterminé avec quatre négatifs convergents, talon lisse, 6 : pointe Levallois sur éclat débordant avec talon lisse, 7 : éclat semi-cortical avec talon lisse et négatifs unidirectionnels, 8 : pointe Levallois à talon dièdre obtenu par la modalité récurrente unidirectionnelle, 9 : pointe Levallois, 10 : lamelle torse avec talon lisse, 11 : éclat de réaménagement, 12 : nucléus à lamelles, 13 : nucléus à lamelles fragmenté, avec quatre négatifs.

(A1)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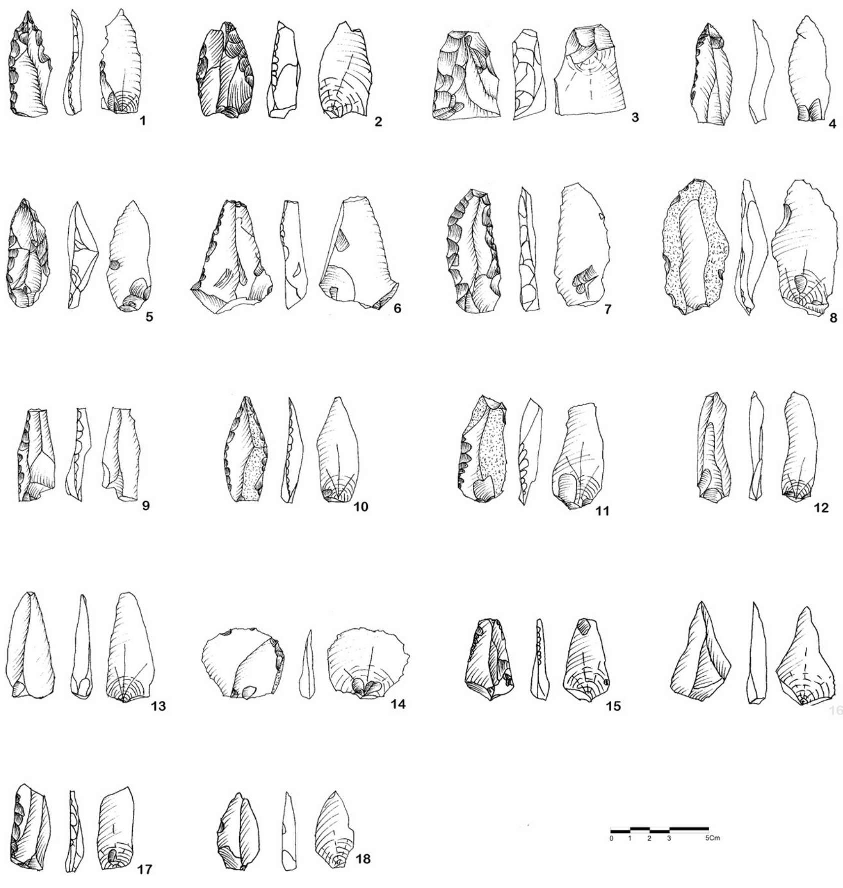
(A2)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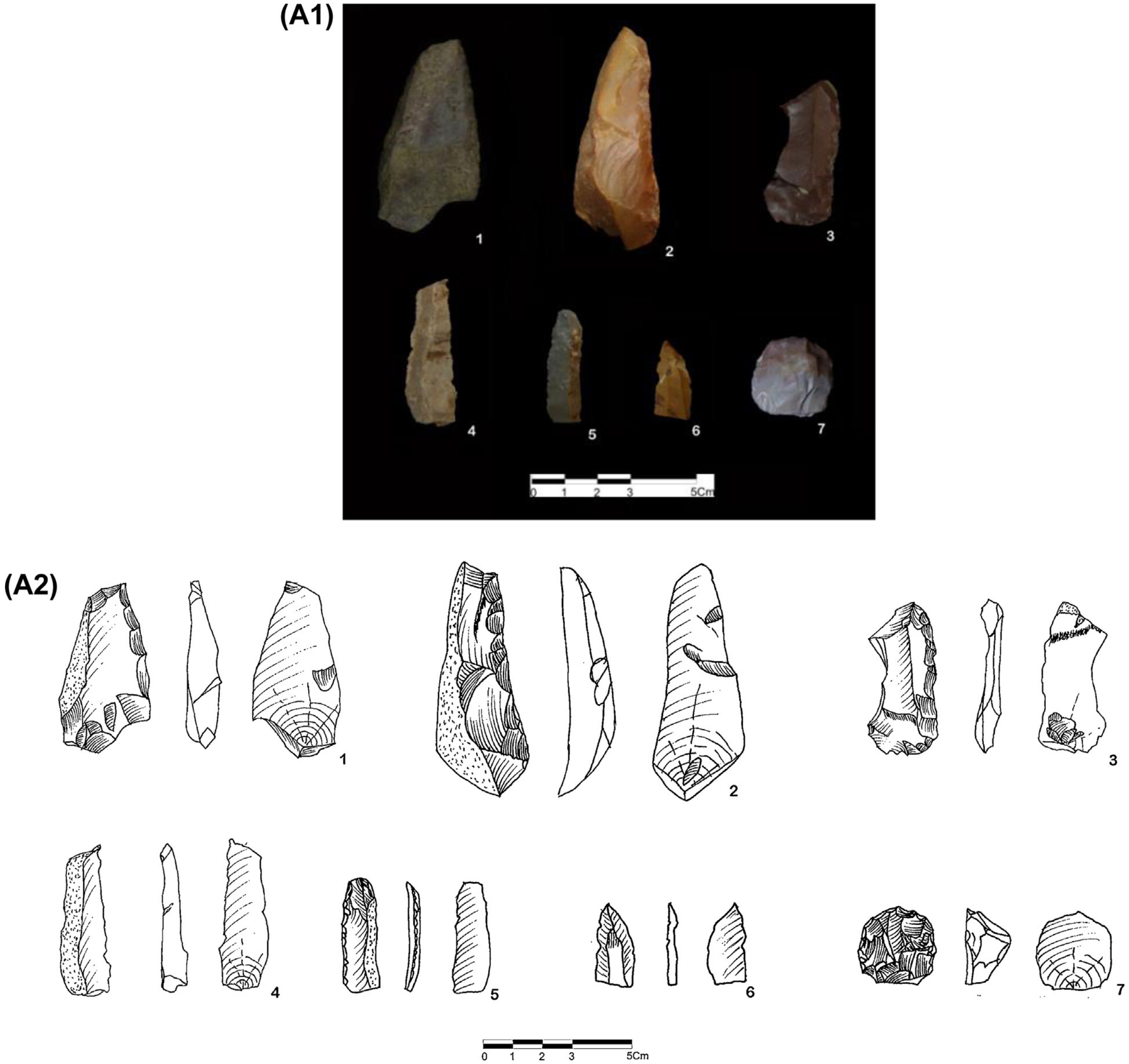

Fig. 7. (Color online). A1 and A2. Selected artifacts from Gar Arjeneh Rock Shelter. 1 and 2: Side-scraper on cortical flake with flat platform, 3: Fractured side-scraper with dihedral platform, 4: cortical blade, 5: fractured retouched bladelet, 6: pointed fractured bladelet, 7: discoid core.
Fig. 7. (Couleur en ligne). A1 et A2. Sélection d'artefacts de l'abri Gar Arjeneh. 1 et 2 : racloir cortical avec talon lisse, 3 : racloir fragmenté avec talon dièdre, 4 : lame corticale, 5 : lamelle retouchée fragmentée, 6 : lamelle appointée, 7 : nucléus discoïde.

Fig. 6. (Color online). A1 and A2. Selected artifacts from Ghamari Cave level 5 and 4: 1: Mousterian point on a Levallois flake with faceted platform, 2: Mousterian point with a flat platform and distal fracture, 3: Mousterian point on a Levallois unidirectional convergent flake, 4: Mousterian point with flat platform and distal fracture, 5: limace, 6: side-scraper on core-edge flake, 7: side-scraper with flat platform, 8: semi- cortical flake with flat platform, pseudo retouch on both sides, three unidirectional negatives, 9: fragmented side-scraper with flat platform, 10: side-scraper on cortical flake with flat platform, one parallel unidirectional extraction and open internal flaking angle, 11: side-scraper on cortical flake with flat platform, 12 and 13: Levallois point with dihedral platform, 14: Levallois flake with faceted platform, 15: fractured pointed flake with dihedral platform and pseudo retouch on the left side, 16: fractured overshot pointed flake, 17: fractured side-scraper with flat platform, 18: fractured pointed flake.
Fig. 6. (Couleur en ligne). A1 et A2. Sélection d'artefacts de la grotte Ghamari, niveaux 5 et 4. 1 : pointe moustérienne à talon facetté, 2 : pointe moustérienne à talon lisse, fracturée, 3 : pointe moustérienne sur éclat Levallois unidirectionnel convergent, 4 : pointe moustérienne à talon lisse, fracturée, 5 : « limace », 6 : racloir sur éclat débordant, 7 : racloir à talon lisse, 8 : éclat cortical à talon lisse avec pseudo-retouches et trois négatifs unidirectionnels, 9 : racloir fragmenté avec talon lisse, 10 : racloir cortical, avec un négatif parallèle unidirectionnel, 11 : racloir cortical à talon lisse, 12 et 13 : pointes Levallois à talon dièdre, 14 : éclat Levallois à talon facetté, 15 : éclat appointé fragmenté à talon dièdre et pseudo-retouches sur le côté gauche, 16 : éclat appointé fragmenté, 17 : racloir fragmenté avec talon lisse, 18 : éclat appointé fragmenté.

Fig. 8. (Color online). 1: KLD-DS-5 + KLD-1—right lower canine of a male *Sus scrofa* from Kaldar Cave; lingual view; 2: GLV-A1-17-enamel fragment of a cheek tooth of a rhinoceros (?) from Gilvaran Cave; (a) buccal view, and (b) section; 3: KLD-11 – tip of the tine of an antler of Cervidae indet. cf. *Cervus elaphus*; (a) anterior/posterior, (b) lateral/medial, (c) anterior/posterior, and (d) lateral/medial views, and (e) section; 4: GLV-A8-103—fragment of a lumbar vertebra of Cervidae indet. cf. *Cervus elaphus* from Gilvaran Cave; posterior view; 5: KLD-9—fragment of the pincer of a crab from Kaldar Cave; (a) distal section, (b) mesial view, (c) occlusal view, (d) lateral view, (e) inferior (?) view, and (f) proximal section; 6: GHM-F2-8—right P2 of Bovini indet. from Ghamari Cave; (a) occlusal, (b) buccal, and (c) lingual views; 7: KLD-14—first phalanx right of the axis of the hand (?) of *Capreolus* from Kaldar Cave; (a) distal, (b) proximal, (c) axial, (d) dorsal, (e) abaxial, and (f) plantar views. 8: GHM-F2-22 – axis of *Hystrix* from Ghamari; (a) anterior, (b) posterior, (c) right, (d) dorsal, and (e) ventral views; 9: KLD-10 – left M1/2 (M1?) of *Capra* from Kaldar Cave; (a) buccal, (b) occlusal, and (c) lingual views. The scale bars represent 1.5 cm for photographs 2 and 5 and represents 3 cm for the remaining photographs.

Fig. 8. (Couleur en ligne). 1 : KLD-DS-5 + KLD-1, niveau 4–canine inférieure droite d'un mâle *Sus scrofa* de la grotte Kaldar ; vue linguale ; 2 : GLV-AY1-17, niveau 4-fragment d'émail d'une dent de rhinocéros (?) de la grotte Gilvaran ; (a) vue buccale, (b) vue en section ; 3 : KLD-11, niveau 5–point d'andouiller de Cervidae indét. cf. *Cervus elaphus* ; (a) vues antérieure, (b) médiale, (c) postérieure, (d) latérale, (e) section ; 4 : GLV-A8-103, niveau 2–fragment d'une vertèbre lombaire de Cervidae indet. cf. *Cervus elaphus* de la grotte Gilvaran ; vue postérieure ; 5 : KLD-9, niveau 5–fragment de pince de crabe de la grotte Kaldar ; (a) section distale, (b) vue mésiale, (c) vue occlusale, (d) vue latérale, (e) vue inférieure, (f) section proximale ; 6 : GHM-F2-8, niveau 4–P^2 droite de Bovini indet. de la grotte Ghamari ; vues (a) occlusale, (b) buccale, (c) linguale ; 7 : KLD-14–première phalange, droite de l'axis de la main (?) de *Capreolus* de la grotte Kaldar; vues (a) distale, (b) proximale, (c) axiale, (d) dorsale, (e) abaxiale, (f) plantire ; 8 : GHM-F2-22–axis d'*Hystrix* de la grotte Ghamari ; vues (a) antérieure, (b) postérieure, (c) droite, (d) dorsale, (e) ventrale ; 9 : KLD-10–M1/2 (M1?) gauche de *Capra* de la grotte Kaldar ; vues (a) buccale, (b) occlusale, (c) linguale. L'échelle est de 1,5 cm sur les clichés 2 et 5, et 3 cm pour les autres clichés.

Hystrix sp. cf. *Hystrix indica*: Ghamari Cave
Gliridae indet.: Ghamari Cave
Mustelidae indet.: Kaldar Cave
Rhinocerotidae indet.?: Gilvaran Cave, level 4.
Sus scrofa: Kaldar Cave
Capreolus sp.: Kaldar Cave, Gilvaran Cave
Cervidae indet. cf. *Cervus elaphus* Kaldar Cave, Gilvaran Cave
Bovini indet.: Gilvaran and Ghamari Caves
Caprini indet. cf. *Capra aegagrus*: Gilvaran, Ghamari, Kaldar Caves

The presence of a crab in Kaldar Cave either suggests that water was very near to the cave at the time the deposits were formed, or that it was brought into the cave by a predator or humans.

In large parts of Europe, the fossil record is sufficiently known to allow fairly precise age estimation, often allowing in assigning fossil associations to a particular glacial cycle or oxygen isotope stage. At present this is not possible in Iran. However, the fossil association is interesting from a biogeographical point of view. The Khorramabad Valley is a passageway across the Zagros Mountains and is situated at the border of the Palearctic and Saharan-Arabian biogeographic realms and not very far away from the Oriental realm (Holt et al., 2013). Dealing here with Pleistocene fossils, we might expect species from these different realms. However, the taxa identified here, and those known from the literature (Marean, 1998; Mashkour et al., 2008, 2009, 2012; Trinkaus and Biglari, 2006; Trinkaus et al., 2008), suggest that, the humans in this area lived in a Palearctic and more precisely a West Eurasian biogeographic context. This must have had importance for their geographic distribution, contacts with other populations and gene flow, or for their opportunities of dispersal.

Against this biogeographical background it is interesting to note that the fossils of *Capreolus* are the southern-most records of the genus in western Eurasia. The same may be true of *Cervus*. The possible presence of a rhinoceros at Gilvaran Cave is intriguing. An indeterminate species of "*Dicerorhinus*" was cited from the Wezmeh Cave in Iran (Mashkour et al., 2008). That genus lives today in SE Asia, while the related *Rhinoceros* lives also in the Indian Subcontinent. Both have long records in East Asia and the Indian Subcontinent, respectively. However, these authors may have meant the genus *Stephanorhinus*, which previously was included in *Dicerorhinus*, a practice still followed by some. *Stephanorhinus* and the closely related woolly rhinoceros *Coelodonta* are fossil rhinoceroses from northern Eurasia. The latter was cited also from the Indian Subcontinent (Colbert, 1935), while *S. kirchbergensis* and *S. hemitoechus* are described from Azokh Cave in Nagorno Karabach (Van der Made et al., in press). Biogeographically it would be very interesting to know which of these species were present in Iran.

4. Discussion and conclusions

Thanks to the advances made by pioneering researchers, we were able to expand and test their initial results with modern techniques. Although some of our results confirm previous findings, others enable us to advance new data. For instance, Hole and Flannery reported that: "The technique of the Luristan Mousterian is non-Levallois, like that observed elsewhere in the Zagros" (e.g., Shanidar, Hazar Merd, Warwasi, Bisitun) (Hole and Flannery, 1967: 155; see also Vahdati Nasab, 2010). However, we recovered many Levallois points, pointed flakes, flakes and Levallois cores not only at Gilvaran and Kaldar, but also at Ghamari, where these had not previously been reported. Regardless of these differences, our results are in general agreement with Hole and Flannery's categorization of technologies from these sites.

Parviz recorded Gilvaran as an Upper Paleolithic locality. Roustaei et al. (2004) stated that: "The two large collections from Sorkh-e Lizeh and Gilvaran I exhibit some generic early Upper Paleolithic characteristics (e.g., many flakes, retouched pieces made on flakes, flake cores, denticulates and notches, side-scrapers), but they occur along with lamellar elements and even bullet cores" (Roustaei et al., 2004: 8). However, we recovered a large number of Middle Paleolithic tools in the A8 and AY1 trenches from this site (several types of typical Mousterian, Levallois, *limace*, Tayac and déjeté points, side-scrapers and blades from Levallois cores. According to their report: "Hammer stones and grinding stones were reported by Hole and Flannery (1967) from their tests at Gar Arjeneh and also show up at Gilvaran I but are of uncertain chronological or diagnostic significance" (Roustaei et al., 2004: 9). From this, it is clear that a surface collection does not allow assessment for a reliable chronology and that the recent excavations in the Khorammabad Valley provide new data necessary to fully understand these lithic assemblages.

Apart from documenting two more Middle Paleolithic localities in the Khorramabad Valley, the recognition in our excavations of two distinct but continues levels in level 5 of Gilvaran cave is of vital importance, because it might help in understanding some of the dark angles of the possible interaction between *Homo sapiens* and the Neanderthals and the causes of the extinction of the latter.

Another important issue, which is one of the main objectives of this research, is the beginning of the Middle Paleolithic period in this area. "The true age of the Mousterian in the Zagros is not known, although carbon from Kunji Cave gave a radiocarbon date of greater than 40,000 years" (Hole and Flannery, 1967). However, relying on 1970s dating, we may know, more or less, the end of Middle Paleolithic age of Khorramabad Valley. "An important point is that in case of absolute dating; most of the Paleolithic sites in Iran suffer from the lack of reliable dating techniques (e.g., some of the dates obtained by ^{14}C techniques prior to the 1970 could be drastically changed because of absence of reliable calibration at the time)" (Vahdati Nasab, 2011).

Although new radiometric dating is still in progress, the techno-typological similarities between the sites investigated and the nearby Yafteh Cave permit to associate the radiocarbon dates of the latter (Otte et al., 2011) for timing the appearance of the Upper Paleolithic in the Khorramabad Valley. The Mousterian tradition instead might be older than expected. The preliminary paleontological study confirms that faunal affinities are predominantly European and adds a new taxon which has its southern-most distribution in the area. When more extensive collections are studied in detail, biostratigraphy has the potential to contribute to dating the different levels and making paleoecological interpretations.

Our preliminary study also shows that modern and systematic excavations may provide information that challenges the classical views on the technology of the stone tools of this area. A brief study of the lithic assemblages of all the sites shows that the raw materials used are mostly pebbles from the Khorramabad River. Field observations indicate that the majority of the caves and rock shelters in the region are close to water sources, mainly the Khorramabad River. The assemblages are dominated by relatively high-quality raw materials procured as pebbles from local gravels.

In the fluvial deposits in the valley, there are pebbles and cobbles of many different colors and quality (dominated by chert stone) easily available. Flint is easy to find and it therefore seems a convenient source for the Paleolithic hunters and gatherers inhabiting this area. As a result, it is not unreasonable to think that the majority of the knapped materials in the sites are of local origin.

Except a single obsidian microlith blade in the AY1 trench in the Gilvaran, chert is the predominant raw material in all the sites (SOM Fig. 8). As far as we know, the nearest obsidian sources are in the Caucasus and Turkey. "The most important sources of obsidian in the Near East are located in Anatolia and Caucasus. There are also smaller sources in southern Yemen, possibly in southwest Arabia and the Red Sea islands (Francaviglia, 1990; Zarins, 1989), and perhaps some localities in Iran, yet to be explored" (Abdi, 2004).

The preliminary technological analyses of the lithic assemblages indicate in the Mousterian the exclusive use of the Levallois recurrent unidirectional methods with the shift to the centripetal modality at the end of the flaking sequence. The dimension of the raw material plays also an important role in the choice of the knapping method, as is the case in small discoid cores. The retouched artifacts are dominated by Mousterian and elongated points, side-scrapers, déjetés and convergent scrapers. These features are common in the other sites of the Zagros regions during the late Middle Paleolithic indicating a certain technological stability. In the lithic assemblages of the Upper Paleolithic instead is documented a technological change towards the production of blades and retouched bladelets. Within the retouched tools it is worth noting the production of Arjeneh points that are exclusive of these territories, suggesting an in situ development of these artifacts in the Baradostian tradition. Recent examinations of the Upper Paleolithic assemblages of Warsawi and Yafteh Caves highlighted the independence of these technological innovations that are not rooted in the Mousterian tradition as was traditionally stated. It is one of the aims of our future research to know more about environmental conditions and constraints in order to better understand technological and behavioral evolution. For this end, we intend to study the lithics by means of microwear and residue analysis to understand the function of the tools and the features of the behavioral changes and transition. We are also studying the fossils remains to better assess the faunal changes between those periods. To obtain all of this knowledge, a wide comparison analysis of assemblages in the area is of vital importance.

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Appendix A. Supplementary data

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Supplementary On-line Material

Palaeontology

Material and Methods

A small collection of the fossils from the excavations in the Khorramabad Valley was taken to Tarragona and has been studied in detail. Those specimens are presently (and temporarily) kept in the IPHES and were compared to fossil and recent animals. Most of the comparisons are with recent mammals from the IPHES collections. Where comparative data are explicitly cited, the acronym of the institution where the material was studied, or where it is presently kept, is given: ASM = Artsakh State Museum, Stepanakert; AUT = Aristotle University of Thessaloniki; FASMN = Römisch-Germanisisches Zentralmuseum, Forschungsinstitut für Vor- und Frühgeschichte, Forschungsbereich Altsteinzeit Schloss Monrepos, Neuwied; CIAG = Centre d'Investigacions Arquelògics de Girona; GSM = Georgian State Museum, Tbilisi; HUJ = Hebrew University, Jerusalem; IPHES = Institut Català de Paleoecologia Humana i Evolució Social, Tarragona; IPUW = Institut für Paläontologie der Universität, Wien; IQW = Institut für Quartärpaläontologie, Weimar. (at present: Senckenberg Forschungsinstitut und Naturmuseum, Forschungsstation für Quartärpaläontologie, Weimar); LVH = Landesmuseum für Vorgeschichte, Halle; MNCN = Museo Nacional de Ciencias Naturales, Madrid; MRA = Museum Requien, Avignon; MUB = Medical University, Baku; MNB = Museum für Naturkunde der Humboldt-Universität, Berlin; NNML = Nationaal Natuurhistorisch Museum, Leiden; NMP = National Museum, Prague.

Measurements were taken according to Van der Made (1996) and Van der Made & Tong (2008). The measurements are given in mm and are indicated with the following acronyms: DAP = antero-posterior diameter (maximum or at the occlusal surface of a tooth); DAPd = DAP of the distal part of a bone; DAPp = DAP of the proximal part of a bone or DAP of the posterior lobe of a tooth; DAPb = DAP at the base of the crown of a tooth; DLL = labio-lingual diameter of an incisor; DMD = mesio-distal diameter of an incisor; DT = transverse diameter; DTa = DT of the anterior lobe of a tooth; DTd = DT of the distal end of a bone; DTp = DT of the proximal end of a bone or of the posterior lobe of a tooth; Ha = height of the crown of a molar measured at the lingual (lower) or buccal (upper) side of the anterior lobe; Hli = height of the crown of an incisor measured at the lingual side; L = length; Li = width of the lingual side of the male lower canine in suids.

Systematic description, comparison and discussion.

The most indicative specimens of the small collection that was taken to the IPHES are described below.

Crustacea indet. A pincer of a crab was recovered from Kaldar Cave (Figure 8-5). The fragment has a length of 12.8, greatest width of 7.4 and height of 6.9 mm.

Rhinocerotidae indet.? An enamel fragment from Gilvaran Cave, level 4 (Figure 8-2) has a length of over 19, a width of over 7, and a thickness of about 2.7 mm. The surface is flat and very smooth. The fragment must have belonged to a large tooth with an extensive flat surface. It may have formed part of the buccal surface of an upper tooth of a rhinoceros. Species like *Stephanorhinus hemitoechus* and *Coelodonta antiquitatis* have enamel that is more crenelated. Species with relatively smooth enamel include *Stephanorhinus kirchbergensis* and *Rhinoceros unicornis*. In any case, the presence of a rhinoceros should be considered to be tentative.

An unidentified species of "*Dicerorhinus*" was cited from the Wezmeh Cave in Iran (Mashkour et al., 2008). *Dicerorhinus sumatrensis* is a species that lives in SE Asia, while *Rhinoceros unicornis* is the living Indian species (Duff & Lawson, 2004). Both genera have long fossil records in in East Asia and the Indian Subcontinent, respectively (Colbert, 1935; Xue & Zhang, 1991). However, it was custom to assign the European and North Asian rhinoceroses to *Dicerorhinus*, that are now placed in *Stephanorhinus* and this may have been meant in the case of the material from Wezmeh Cave. *Stephanorhinus kirchbergensis, S. hemitoechus and Coelodonta antiquitatis* are the typical West Eurasian species for the late Middle and Late Pleistocene of western Eurasia (Guérin, 1980; Van der Made, 2010; Van der Made & Grube, 2010). The first two species have been described from Azokh, in Nagorno Karabach (Van der Made et al. in press). *Coelodonta* was cited from the Indian Subcontinent (Colbert, 1935). From this review it is obvious that it would be very interesting if rhinoceros species could be identified from the Pleistocene of Iran. At present the identification is not possible for the fossil from Gilvaran Cave.

Sus scrofa. A canine from Kaldar Cave (Figure 8-1) has the characteristics of the lower canine of a male suid: it is very high crowned (hypselodont) and has a triangular section with the posterior side lacking enamel and a large facet near the tip. The section is "scrofic", meaning that the posterior side (which lacks enamel) is wider than the labial side, as opposed to a "verrucose" section with the posterior side narrower than labial side. The specimen is large (Li >20.6).

Sus scrofa and the very small *Sus salvanius* are the only species of *Sus* that are known to have canines with "scrofic" sections, while the remaining species of *Sus* have "verrucose" sections. The size of the specimen from Kaldar is far superior to that of the canines of *Sus salvanius*. *Sus scrofa* is also present in Gilvaran Cave and has been cited or described from Wezmeh, Bisitun and Yafteh Caves in Iran (Trinkaus & Biglari, 2006; Mashkour et al., 2008; Maskour et al. 2012), as well as from Azokh Cave in Nagorno Karabach (Van der Made et al. in press) and Shanidar in Iraq (Evins, 1982), which are not very far away from the Khorramabad Valley.

The wild boar *Sus scrofa* appeared not later than some 800 ka ago in Western Europe (Van der Made, 1999; Franzen et al., 2000). It must have come from Asia, but at present older records have not been documented there. At present it lives in an area that extends from western Europe and Morocco to Japan and Indonesia, including Iran. In most of this area it is the only suid species since the beginning of the Middle Pleistocene onwards, but in Nepal and surrounding areas it is sympatric with the very small *Sus salvanius* and in SE Asia it is sympatric with *Sus barbatus* and *Sus verrucosus* (Duff & Lawson, 2004).

***Capreolus* sp.** A first (or "proximal") phalanx (Figure 8-7) from Kaldar Cave has a morphology as occurs in artiodactyls. It is narrower than in the Suidae. The proximal side is wide and its dorsal edge is flat, but this is at least partially due to the fact that the proximo-dorsal area is slightly damaged there. The articular surface axial of the dorso-plantar grove is narrow, but is wider in a specimen from Gar Arjeneh rock shelter (Figure 9-2). In both specimens, the facets for the sesamoids are small. The measurements of the first specimen are: DAPp >15.2, DAPpf >12.9, DTp = 10.9, L = 41.7, DAPd = 8.4, DTd = 10.7. Those of the second are: DAPp = 15.6, DAPpf = 15.6, DTp = 13.0. Metrically the complete phalanx is narrower than in typical Caprini, such as *Capra, Hemitragus* and even *Ovis*, but somewhat wider than in recent *Gazella* and *Axis* (SOM Figure 9, DTp-L diagram). Despite its proximo-dorsal damage, the phalanx is proximally relatively narrower than in *Saiga* or slender caprines like *Rupicapra* (SOM Figure 9, DTp-DAPp diagram). The distal articulation is wider than in *Antilope*, *Saiga* and *Gazella* (SOM Figure 9, DTd-DAPd diagram). In one or another bivariate diagram the specimen from Kaldar Cave is separate from each of the taxa with which it was compared, save for *Capreolus.* (Surprisingly, this result could not be obtained in a single diagram of the principal components.) The two specimens tend to be large or larger than their homologues in *Capreolus capreolus*.

Being small and simple bones, sesamoids are generally not studied. However, it is possible to assign them to taxa and even they may help to determine a taxon. Artiodactyls have in each finger or toe two sesamoids at the plantar side proximal to the first phalanx and a third one proximal to the third phalanx. The latter is wide and low and the former two are long and narrow. Of these the axial one is "low" (with a short dorso-plantar diameter) and the abaxial one is "high". A sesamoid from Gilvaran Cave (SOM figure 10-1) had the morphology of an axial sesamoid of an artiodactyl. It has a plantar surface with rounded edges (SOM Figures 10-1a & f), like in cervids (SOM Figures 10-2a & f, 10-3a & f), whereas in bovids (or at least caprines) this surface tends to be flatter (in transverse direction) and tends to form more clearly defined angles with the axial and abaxial sides of the bone, particularly making a sharp angle with the abaxial side (SOM Figures 10-4a & f; 10-5a & f). In suids this angle is even much sharper. The specimen from Gilvaran has the size (DPD = 11.0, DT = 5.6, DDPmax ≥6.0, DDPmini = 5.9) of the axial sesamoid behind the first phalanx of a *Capreolus*. In the diagram in SOM Figure 10 the *Capreolus* sesamoids form two clusters for the manus and pes, respectively, whereas the sesamoids of manus and pes of the same individuals of Caprini are closer together.

A patella from Gilvaran Cave has a wide facet for the femur. There is a clear angle in the facet, while in the Caprini it is more rounded. The bone is wide (transverse diameter DT = 19.0) and thick (antero-posterior diameter 14.5; its height was superior to 18.9 mm). *Lynx* has a wide and flat patella, while *Canis lupus* has a narrow and thick patella. The patella of *Gazella* is flat with a not so clear angle in the facet. The latter is also the case in *Capra*. *Capreolus* has a relatively thick and wide patella with a clear angle in the middle of the facet. The specimen from Gilvaran is somewhat larger than the specimens from recent *Capreolus capreolus* from Spain we used for comparison (IPHES).

Capreolus capreolus lives from Europe to the area south of the Caspian Sea in northern Iran, while *Capreolus pygargus,* which is larger with larger antlers, lives in an area from north of the Caucasus extending eastward into Asia (Duff & Lawson, 2004; Aulagnier et al., 2009). In Western Europe, the size of *Capreolus* decreased markedly during the Late Pleistocene, while a fossil *Capreolus* from Azokh Cave in Nagorno Karabach is very large (Van der Made et al., in press). Evins (1982) noted that *Capreolus* is a rare element in SW Asia and indicated its presence in Jarmo and "Mousterian levels" of Shanidar Cave in Iraq, but not in Iran. The material was assigned to *Capreolus capreolus*, but there does not seem to be much more than a carpal from the former and a P^2 from the latter locality. This P^2 is indeed not very large and is in the metrical ranges of recent *Capreolus capreolus*. The remains from the Khorramabad valley are relatively large and are in the metrical ranges of, what in Western Europe would be called, *Capreolus priscus* or *C. capreolus priscus*, but could also to belong to *C. pygargus*. While *Capreolus pygargus* ranges far south into China, this is possibly the southernmost record of the genus in western Eurasia.

Cervidae indet. cf. *Cervus elaphus.* The tip of an antler (Figure 8-3) from Kaldar Cave has a length of 3 cm. At one side there is probably some rodent gnawing and apart from this the section is round and has a diameter of about 11 mm. Such tips may occur in *Cervus elaphus*, *Cervus unicolor*, *Cervus duvauceli, Cervus eldi* and *Axis*, as well as in the lower tines in the different species of *Dama*. The fragment is too robust for *Capreolus*.

A fragment of a lumbar vertebra from Gilvaran Cave (Figure 8-4) preserves the right side of the vertebral arch, the cranial articular process, and the base of the transverse process. The transverse process is wing-like as is typical of lumbar vertebras, and is directed outward and slightly forward. The cranial articular process has an S-shaped articular surface, as in cervids, but unlike in bovids, equids and carnivores. The curvature of what is left of the wall of the vertebral foramen indicates that this foramen was relatively high, higher than in *Sus scrofa*. The vertebra seems to belong to a cervid. The S-shaped facet is about the only thing that can be measured in this specimen; its length is 18.6 mm. The general size of the specimen is slightly larger than that of a recent *Cervus elaphus* from Spain, which is a small sized subspecies.

Today the large *Cervus elaphus maral* lives in an area that includes the north of Iran, while *C. e. bactrianus* (Turkmenistan, Afghanistan) and *C. e. hanglu* (Norhern India) are also large, as well as *Cervus duvauceli* and *Cervus unicolor* (both living in India) (Whitehead, 1993; Gurung & Singh, 1996). *Cervus elaphus* has been cited or described from Nagorno Karabach (Lioubine 2002; Rivals 2004; Van der Made et al. in press), NE Irak (Evins, 1982) and from Iran (Trinkaus & Biglari, 2006; Mashkour et al., 2008). In some of these cases, it is not clear on which features the determination is based. It seems likely that the material from Kaldar and Gilvaran Caves belongs to *Cervus elaphus*, but we have to await more material to be able to make a determination based on morphology. If confirmed, these finds represent the southern most record of *Cervus elaphus* en the western part of Eurasia.

Caprini indet. cf. *Capra aegagrus.* Some lower molars (Figure 8-9; SOM Figures, 11-5, 11-6) have high crowns, smooth lingual surfaces, lack an interlobular column at the buccal side and have a caprine fold. Some upper molars (SOM figure 11-1) have buccal walls with three pronounced styles, but no buccal crests departing from the para- and metacone (paraexostyle and metaexostyle; nomenclature Van der Made, 1996) and lack a lingual interlobular column. Such a morphology fits Caprinae, such as *Capra*, *Hemitragus*, *Rupicapra*, and *Ovis*, but also antelopes such as *Saiga* and *Pantholops*. The two lower molars measure DAP=12.9, DAPb=11.6, DTa=7.6, DTp=8.5 (KLD-10) and DAP=18.3, DAPb=15.9, DTa≥8.6, DTp≥8.3, Ha>28.4. The upper molar measures DAP=19.2, DAPb=18.2, DTa≈15.2, DTp≈16.1. The size of these molars is large for *Rupicapra*, *Saiga* and *Pantholops*.

Some lower incisors (SOM Figures 11-2, 11-4) are very high crowned as in Caprinae and *Saiga*. The larger one is possibly a I_2 and has the following measurements: DT = 6.6, DLL = 5.2, DMD = 5.7. The smaller one seems to have a distal facet, so cannot be a canine and should be the I_3. Its measurements are: DT = 4.8, DMD = 4.1, DLL = 4.7. In *Saiga*, the size of the incisiform teeth decreases rapidly from I_1 to the canine, while in the caprines, this cline is not so strong. The I_3 is larger than what is expected in *Saiga*, but would fit *Capra*.

The distal part of a first (or “proximal”) phalanx from sublevel B at Ghamari Cave has the typical morphology of a ruminant (SOM figure 11-3). The morphology of the distal articulation recalls cervids, but is damaged and it is not possible to rule out small bovids. It is smaller (DAPd=12.3, DTd=16.2) than its homologue in *Cervus elaphus*, close in size to that of *Dama dama* and larger than that of *Axis* (Bivariate diagram Figure 11). Peculiar is its small anteroposterior diameter, which might be due to some minor damage of the planto-axial area, but possibly it is real and is a resemblance to phalanges of *Capra* and a difference with *Dama*.

Each of these elements could be assigned to more than one taxon, but all of them could belong to a species of *Capra* or *Hemitragus*, more or less of the size of *Capra caucasica*. Today *Capra caucasica* and *C. cylindircornis* live in the Caucasus, while *Capra nubiana* (or *C. ibex nubiana*) lives in the Arabian Peninsula, *Capra falconeri* and *C. siberica* live in areas that include parts of Afghanistan and Pakistan, *C. aegagrus* lives in southern Iran and *Hemitragus jemlahicus* lives in the Himalaya as far west as the north of India and two other species or subspecies in Oman and Unites Arab Emirates and in the south of India (Duff & Lawson, 2004; Gurung & Singh, 1996; Aulagnier et al., 2009). Relatively little is known of the fossil record of all these species. *Hemitragus* had a wide geographic distribution and *H. bonali* was common in the late Early and most of the Middle Pleistocene of Europe and if not the direct ancestor of the living species, must have been close to their common ancestor. Fossil material from the Caucasus was assigned to *C. aegagrus* and *C. caucasica* (Lioubine 2002; Touchabramichvili 2003; Rivals 2004; Van der Made et al. in press). *Capra aegagrus* was cited from Shanidar in NE Irak (Evins, 1982). Fossil material from Iran was assigned to *Capra aegagrus* (Marean, 1998; Mashkour et al., 2008) or/and indefinite species (Mashkour et al., 2009). It is generally not clear on which features the specific assignation is based. Whereas the different species can be recognized by their external morphology, it is more difficult to recognize their bones or teeth. Important differences exist in horn core morphology, and there are minor differences in size. It is likely that the material from the Khorramabad Valley belongs to *Capra aegagrus*, but more material is needed to confirm such an assignation with morphology or biometrics.

Bovini indet. The presence of a bovine in Ghamari Cave is indicated by a second upper premolar (Figure 8-6). It is a large (DAP≥19.3, DAPb≥18.2, DT ≥15.3) and high crowned tooth. Numerous fragmentary fossils indicate the presence of a bovine in Gilvaran and Ghamari Caves. Some of the remains belonged to individuals of very large size. *Bos*, *Bison* and *Bubalus* all occured in the Middle to Late Pleistocene of both Europe and the Indian Subcontinent. Indian *Bubalus* reached very large sizes. *Bison* was cited or described from Azokh Cave in Nagorno Karabach (Lioubine 2002; Rivals 2004; Van der Made et al. in press), which is not so far away from Khorramabad. Fossil auerochs *Bos primigenius* or an unidentfied species of *Bos* have been cited from Iran (Mashkour et al, 2008; Trikaus & Biglari, 2006; Mashkour et al., 2012) and the auerochs has been cited tentatively from Shanidar in northern Irak (Evins, 1982). The studied remains from Ghamari Cave do not allow a precise assignation.

***Hystrix* sp. cf. *Hystrix indica*.** An axis from Ghamari (Figure 8-8; SOM figure 12-2) has a dorsal spine that is posteriorly high (17.3 mm from the vertebral foramen to the tip). In Carnivora it is low. The “tooth” is flattened with a relatively flat ventral facet, which is not confluent with the obliquely oriented antero-lateral facets. This is unlike in ruminants. In Proboscidea and Perissodactyla the bone is much larger and in Lagomorpha and even the largest Insectivora (eg. *Erinceus*) it is much smaller. In primates and a large rodent, like *Castor*, the bone is much shorter. The bone has many resemblances to its homologue in *Hystix cristata* (SOM figure 12-1), but also many minor points of difference: the shape of the “tooth” and the circumference of the posterior articulation (the fossil is of a juvenile and the articular surface is not fused) and it is more robust. The minimal width in the middle is 22.4, the width at the anterior facets is 27.2 and at the posterior facets 22.1 mm. The length at the lower side of the specimen is 22.0 mm. The total height is 37.9. mm. Several other vertebra seem to belong to the same species and probably even the same individual.

Hystrix cristata is the largest living species of the genus and is larger than the European fossil forms, but the living species *Hystrix indica* is nearly as large. The latter species occurs today in Iran (Aulagnier et al., 2009) and has been cited from the Iranian Late Pleistocene (Mashkour et al., 2009). It is possible that the material from Ghamari Cave belongs to that species, but this needs to be confirmed.

Micromammals. The small mammals have been identified by comparing with the fossil collections which are housed at IPHES. SOM Table 1 shows the list of most indicative specimens that we have identified.

Taxa	Anatomic part	Level	Site
Gliridae	femur	level 5	GHAMARI
Mustelidae	fragmented femur	level 5	KALDAR
Mustelidae	fragmented femur	level 5	KALDAR
Leporidae?	distal epiphysis femur	level 5	KALDAR
Erinaceidae	fragmented humerus	level 5	GHAMARI
Gliridae	humerus	level 4	KALDAR
Chiroptera indet.	proximal epihysis femur	level 4	GHAMARI
Rodentia indet.	distal epiphisis humerus	level 4	GHAMARI

SOM Table 1.List of identified micromammals from the Khorramabad sites.

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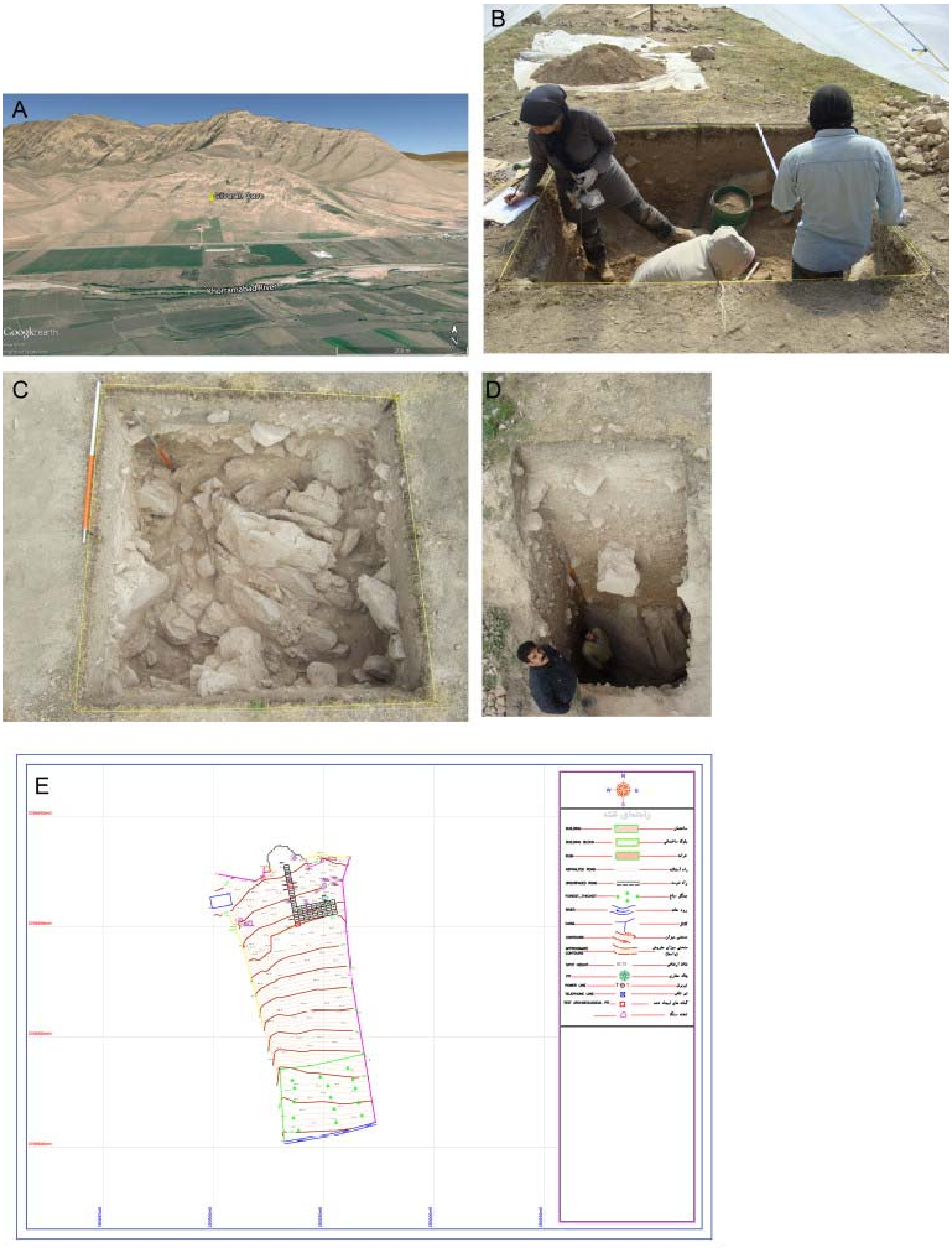
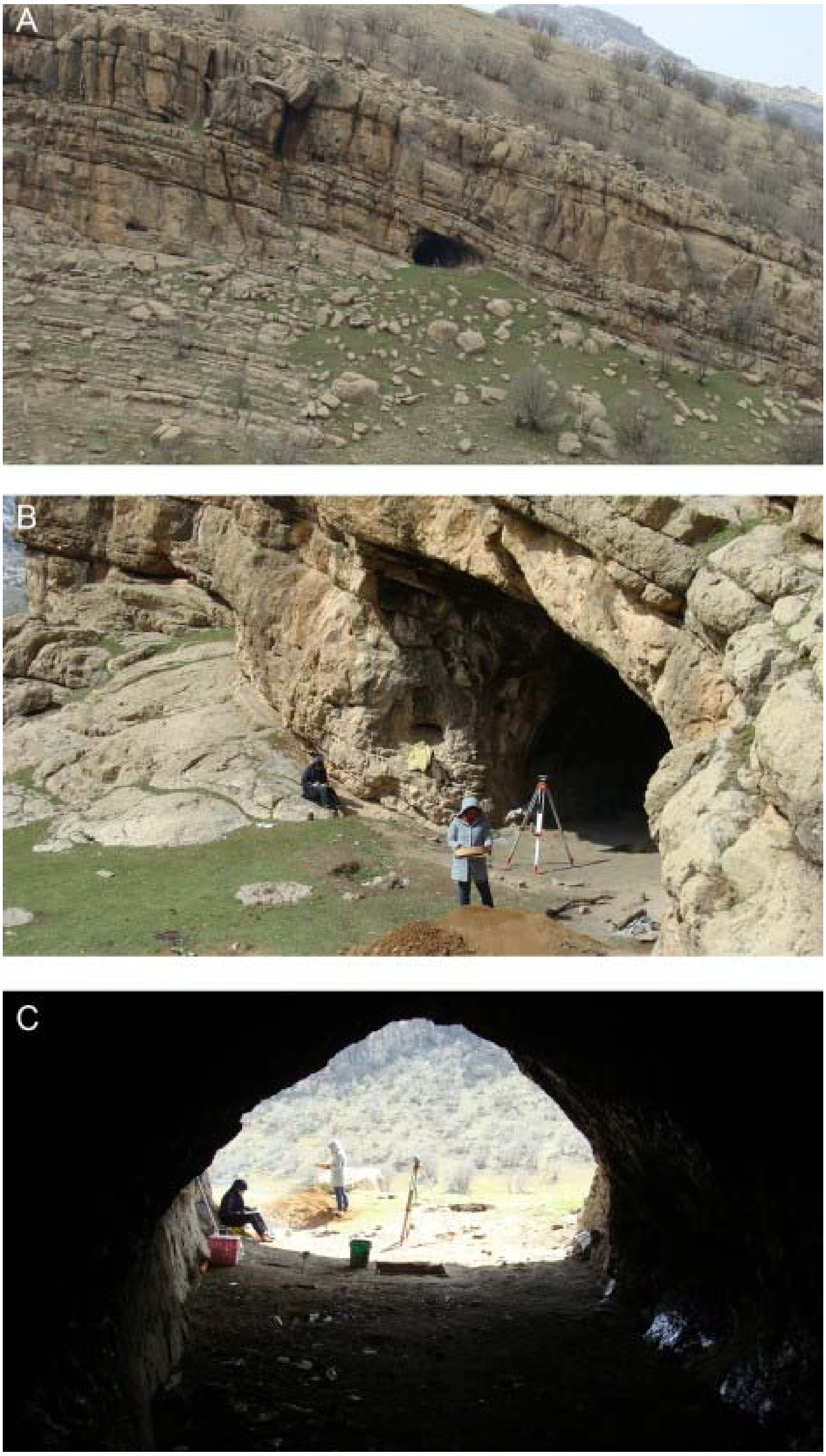


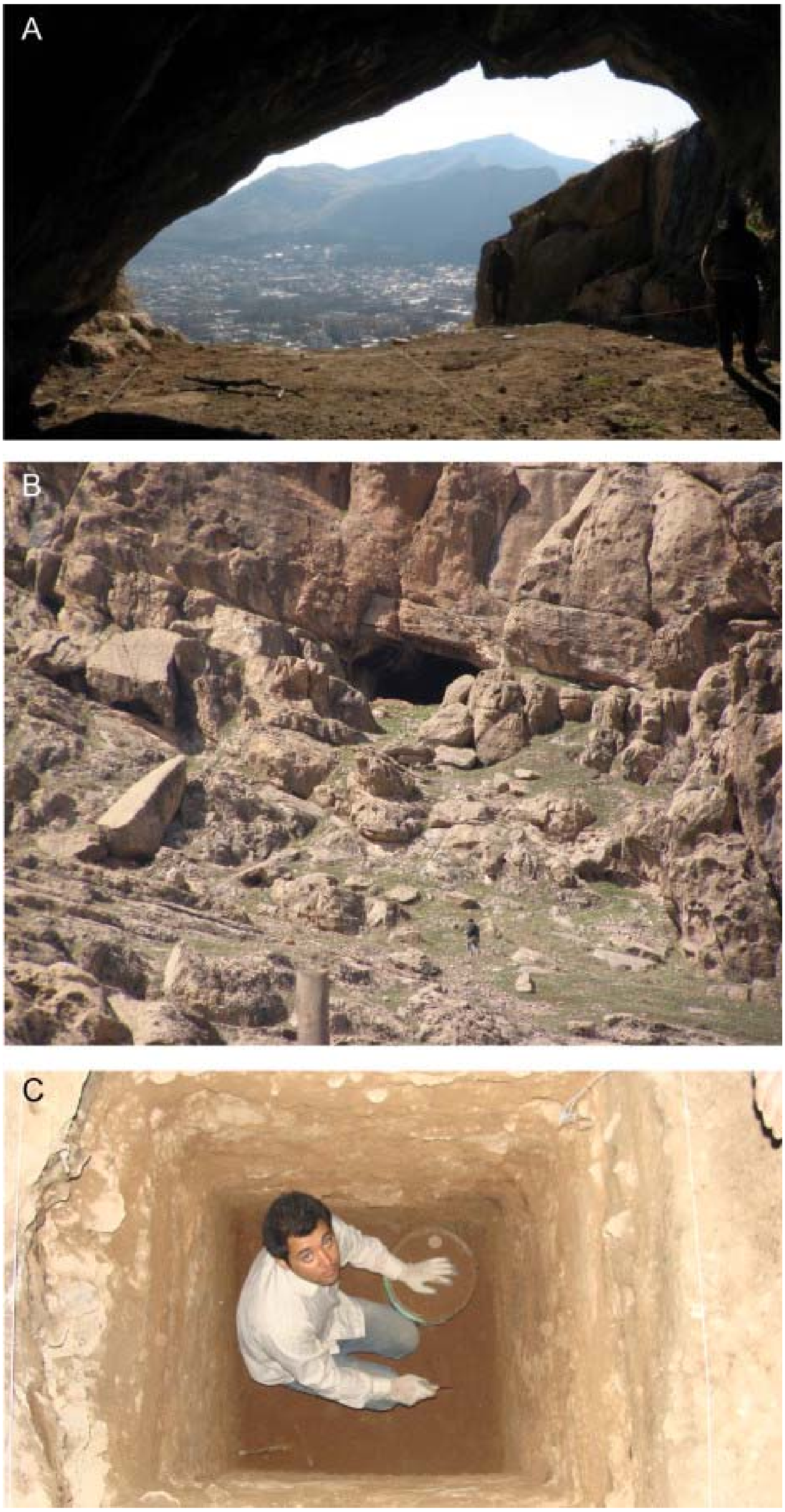
SOM Figure 1. Gilvaran Cave: A) Aerial view and present position relative to the Khorramabad River, general view,B) Excavation of the A8 trench C) A8 trench, exposed huge collapsed rocks D) Position of AY1 trench E) Detailed topography of the cave and surroundings.

SOM Figure 1. Grotte de Gilvaran : A) Vue aérienne et position relative de la Riviére Khorramabad, B) fouilles de la tranchée A8, C) Tranchée A8, énormes rochers effondrés; D) Position de la tranchée AY1 E) Topographie détaillée de la grotte et ses environs.



SOM Figure 2. Kaldar Cave: A) General view, B), Cave entrance C) View from inside the cave and position of the test pit.

SOM Figure 2. Grotte de Kaldar : A) Vue générale, B) Entrée de la grotte, C) Vue de l’intérieure de la grotte et position du sondage.

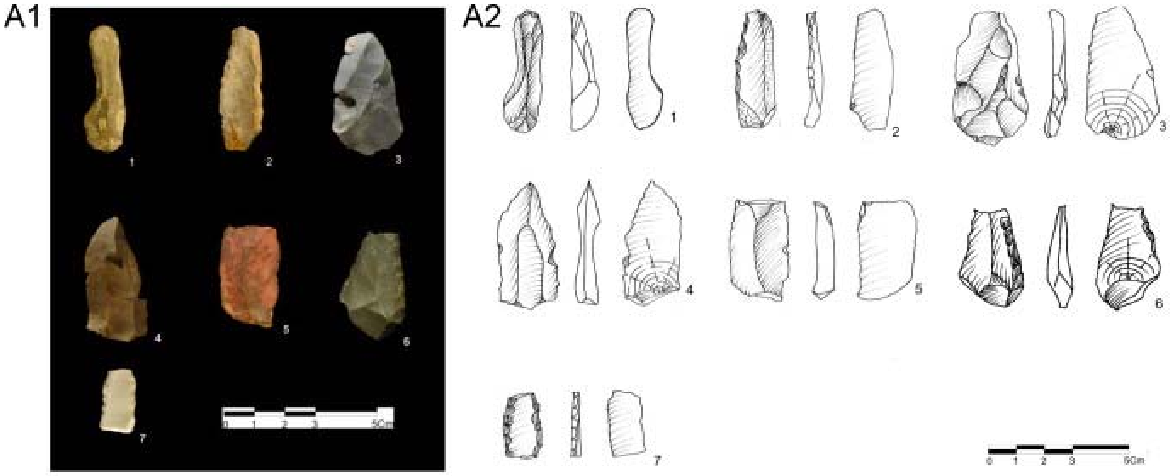


SOM Figure 3. Ghamari Cave: A) Plotting inside the cave B) General view, C) The F2 test pit excavation.

SOM Figure 3. Grotte de Gilvaran : A) disposition intérieure, B) Vue générale, C) Sondage F2.

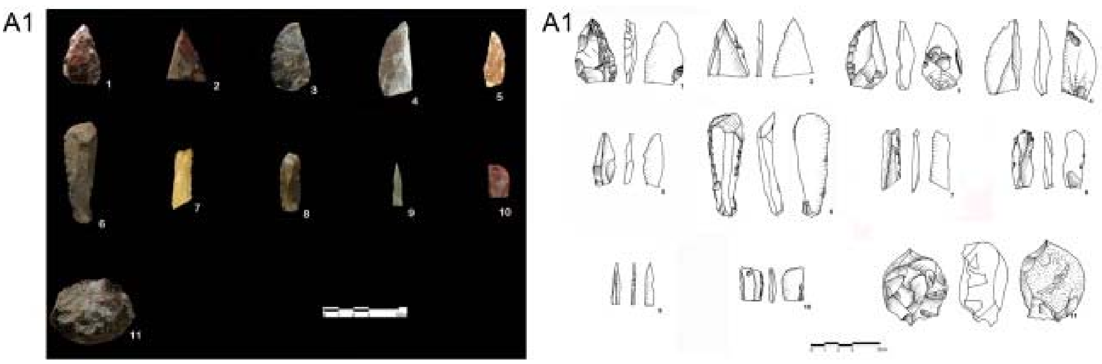
SOM Figure 4. Gar Arjene Rock Shelter: A) General view, B) The H1 test pit excavation, C) The E-4 test pit excavation.

SOM Figure 4. Abri de Gar Arjene : A) Vue générale, B) Sondage H1, C) Sondage E4.



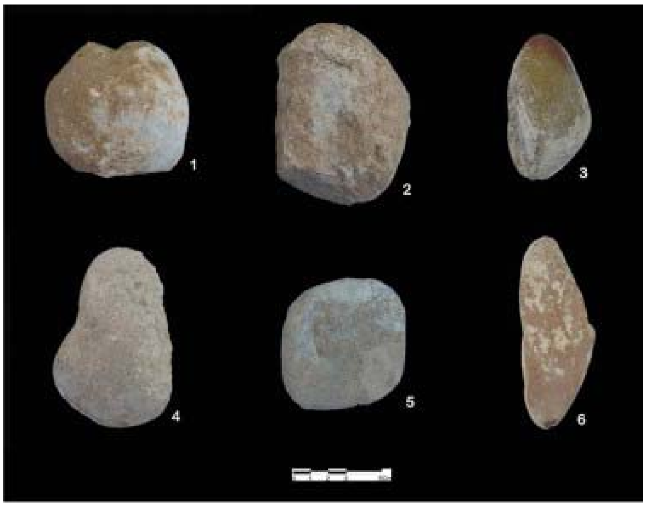
SOM Figure 5. (A1&A2). Selected artifacts from Gilvaran Cave-AY1, level 5&4: 1) Endscraper 2) Sidescraper on natural core- edge blade 3) Pointed flake with dihedral platform 4) Pointed flake with flat platform and pseudo retouch 5) Burnt blade fragment with pseudo retouch 6) Fragment of pointed flake with stepped retouch on the right side 7) Retouched bladelet fragment.

SOM Figure 5. (A1&A2).Sélection d'artefacts de la Grotte Gilvaran-AY1, niveau 5et 4. 1) Grattoir, 2) Racloir sur lame, 3) Éclat appointé à talon dièdre, 4) Éclat appointé avec talon lisse et pseudo-retouch, 5) Lame brulée, 6) Éclat appointé avec retouches scalariformes et pseudo-retouches, 7) Fragment de lame retouchée.



SOM Figure 6. (A1&A2).Selected artifacts from GLV-A8 trench, level 3: 1) Mousterian point, platform is absent, 2) Distal portion of fragmented pointed flake, probably on Levallois blank with pseudo retouch on the right side 3) Sidescraper on core-edge flake with flat platform, the blank could be Levallois recurrent centripetal, 4) Flake produced by Levallois recurrent unidirectional convergent technology, the concretion covers the right side and the platform, 5) Pointed flake, 6), Bilateral retouched bladelet, 7) Fractured blade with retouches on the right side 8) Endscraper, 9) Distal fragment of backed bladelet / Arjeneh point, 10) Burned blade fragment with retouch on the right side, 11) Levallois recurrent unidirectional core.

SOM Figure 6. **(A1&A2).**Sélection d'outils de la tranchée GLV-A8, niveau 3 : 1) Pointe Moustérienne ; 2) Fragment distal d'un éclat appointé sur un support Levallois, 3) Racloir sur éclat latéral à talon lisse, le support peut être Levallois ou récurrent, 4) Éclat produit par Levallois unidirectionnel et convergent, 5) Éclat appointé, 6) Retouches bilatérales sur lamelle, 7) Lame fracturée avec retouches latérales, 8) Grattoir, 9) Fragment distal de lamelle â dos (pointe de Arjeneh), 10) Lame brulée retouchée, 11) Nucleus Levallois.

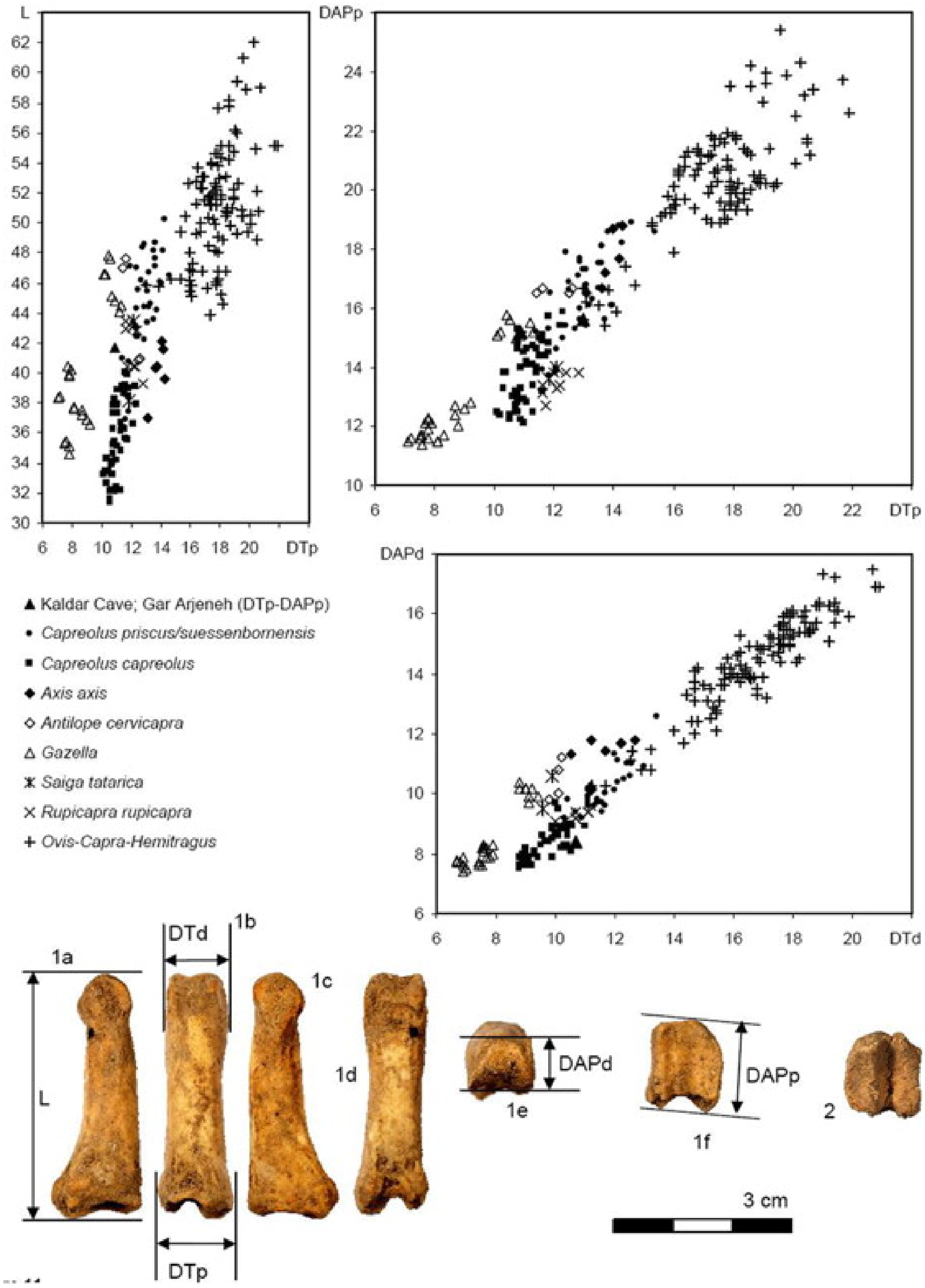


SOM Figure 7. Hammer stones from GLV AY1 & A8 trenches. (1, 2 & 3 AY1 – 4 ,5 & 6 A8).

SOM Figure 7. Percuteur en pierre de GLV AY1 et tranchée 8 (1, 2 & 3 AY1 – 4, 5 & 6 A8).

SOM Figure 8. General and closer view of a Pleistocene deposit of high quality of raw materials in the banks of the Khorramabad River.

SOM Figure 8. Vue générale et détaille d'un dépôt Pléistocène avec des matières premières de bonne qualité sur les rives de la rivière Khorramabad.

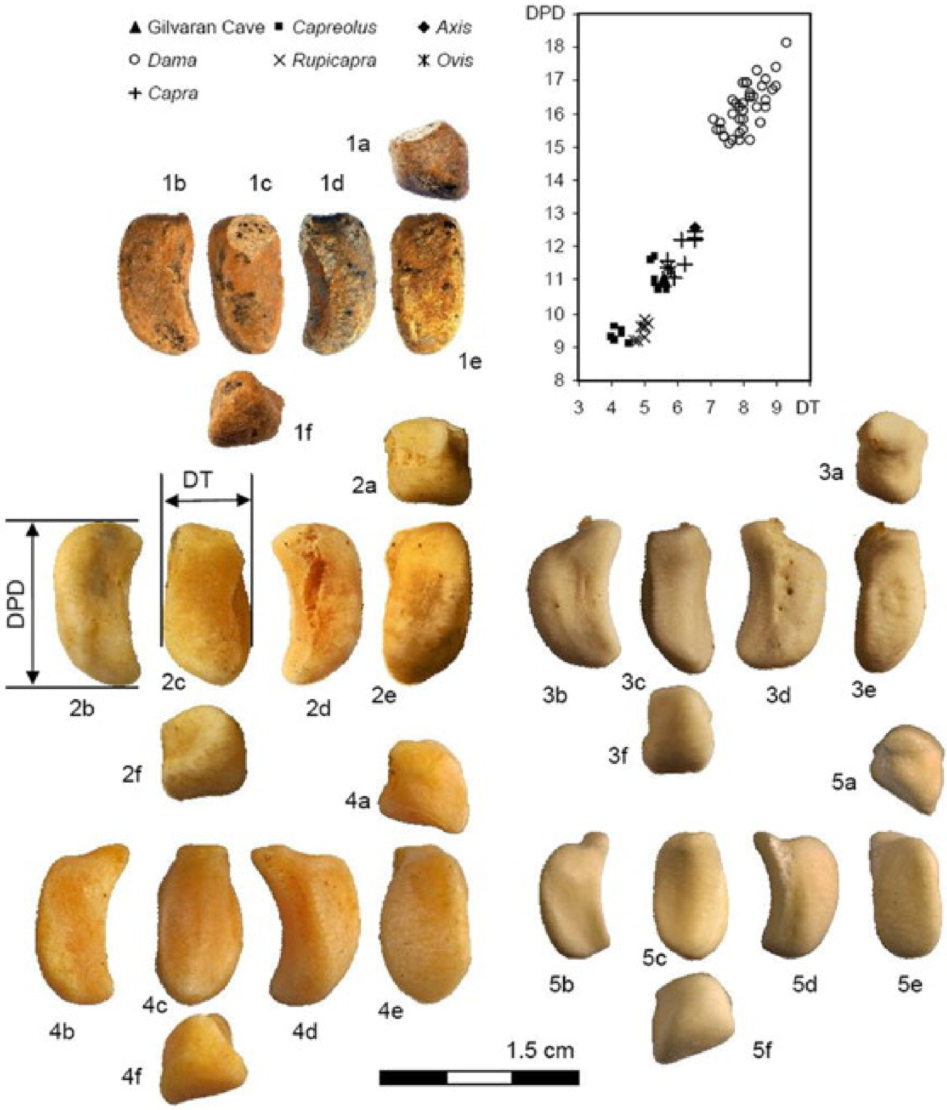


SOM Figure 9: Bivariate diagrams of the first (or proximal) phalanx of: *Capreolus* from Kaldar Cave, level 4 and Gar Arjeneh Rock Shelter (only DTp-DAPp diagram); *Capreolus priscus / suessenbornensis* from Voigtstedt (IQW), Süssenborn (IQW), Koneprusy (NMP), Miesenheim I (FASMN), Azokh V (MUB), Grotte des Cèdres (MRA), Ehringsdorf (IQW); *Capreolus capreolus* from Can Rubau (CIAG), Cueva Morín (MNCN) and recent from Spain (IPHES); recent *Axis axis* (MNCN); recent *Antilope cervicapra* (MNCN); recent *Gazella cuvieri* (MNCN) and recent *Gazella dorcas?* (IPHES, MNCN); recent *Saiga tatarica* (NNML); recent *Rupicapra pyrenaica* (MNCN, all first phalanges of individual no. 14259); and, all together *Capra ibex* from Petralona (AUT); recent *Capra pyrenaica* (IPHES); *Capra caucasica?*from Azykh V (MUB), Ortvala (GSM) and Sakazia (GSM); *Hemitragus bonali* from Hundsheim (IPUW) and feral *Ovis* from Spain (MNCN).

Photographs: 1) KLD-14, level 4 - first phalanx right of the axis of the foot/hand of *Capreolus* from Kaldar Cave; a) axial, b) dorsal, c) abaxial, d) plantar, e) distal, and f) proximal views 2) GRA-5 - proximal epiphysis of first phalanx, left of the axis of the foot from the Gar Arjeneh rock shelter; juvenile, not fused to the diaphysis; proximal view.

SOM Figure 9: Diagramme à deux entrées de la première phalange d'une *Capreolus* de la Grotte Kaldar, niveau 4 et de l'Abri Gar Arjeneh (seulement sur le diagramme DTp-DAPp); *Capreolus priscus / suessenbornensis* de Voigtstedt (IQW), Süssenborn (IQW), Koneprusy (NMP), Miesenheim (FASMN), Azokh V (MUB), Grotte des Cèdres (MRA), Ehringsdorf (IQW); *Capreolus capreolus* de Can Rubau (CIAG), Cueva Morín (MNCN) et récent d'Espagne (IPHES); récent *Axis axis* (MNCN); récent *Antilope cervicapra* (MNCN); récent *Gazella cuvieri* (MNCN) et récent *Gazella dorcas?* (IPHES, MNCN); récent *Saiga tatarica* (NNML); récent *Rupicapra pyrenaica* (MNCN, toutes les premières phalanges de l'individu no. 14259); et ensemble avec *Capra ibex* de Petralona (AUT); récent *Capra pyrenaica* (IPHES); *Capra caucasica?* de Azykh V (MUB), Ortvala (GSM) and Sakazia (GSM); *Hemitragus bonali* de Hundsheim (IPUW) et *Ovis* sauvage de l'Espagne (MNCN).

Photographie: 1) KLD-14, niveau 4 -première phalange droite de *Capreolus* de la Grotte Kaldar; vue a) axiale, b) dorsale, c) latérale, d) plantare, e) distal, et f) proximale. 2) GRA-5 - épiphyse proximale de la première phalange, de l'Abri Gar Arjeneh; jeune individu, diaphyse pas fusionnée; vue proximale.

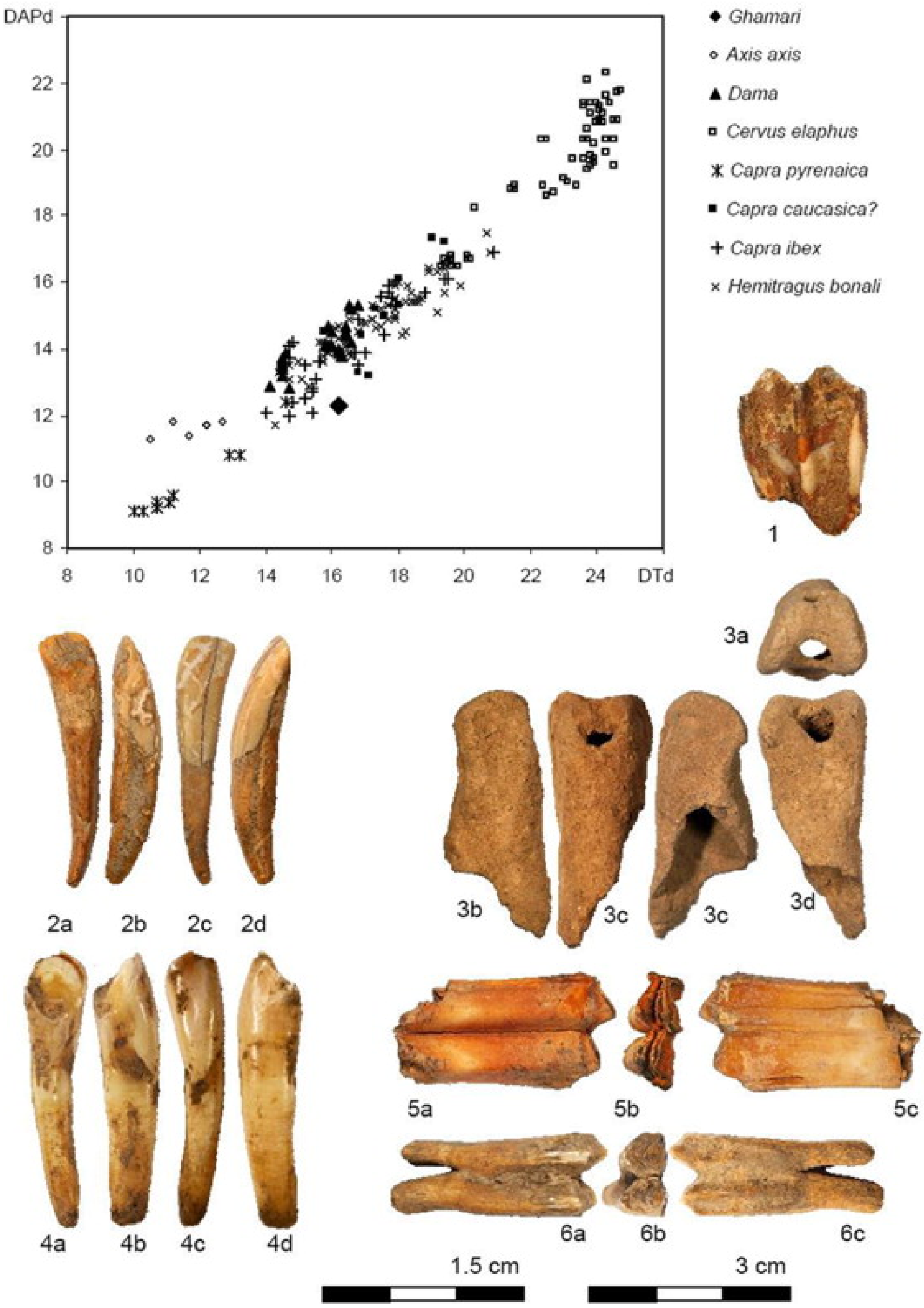


SOM Figure 10. Bivariate diagram of the axial sesamoid behind the first phalanx of: *Capreolus* from Gilvaran Cave, level 5; recent *Capreolus capreolus* from Spain (MNCN); recent *Axis axis* (MNCN); *Dama dama geiselana* from Neumark Nord (LVH); recent *Rupicapra rupicapra* from Spain (MNCN); feral *Ovis* from Spain (MNCN); *Capra pyrenaica* from the Sierra de Gredos (Spain; MNCN).

Photographs: All axial sesamoids from behind the first phalanx, right of the axis of the foot or figured in mirror image (figs 3-5), in each case: a) distal, b) abaxial, c) dorsal, d) axial, e) plantar, and f) proximal views. 1) GLV-AY1-35, level 5 - *Capreolus* from Gilvaran Cave 2) MNCN no number comparative collection Palaeobiology - sesamoid of the manus of *Axis axis* 3) MNCN 21437 - sesamoid of the pes of *Capreolus capreolus* from Otero del Valle (Spain) 4) MNCN 18247 - sesamoid of the manus of *Capra pyrenaica* from the Sierra de Gredos (Spain) 5) MNCN 14259 - sesamoid of the manus of *Rupicapra pyrenaica* from Asturias (Spain).

SOM Figure 10. Diagramme â double entrée de sésamoïde dernière la première phalange de: *Capreolus* de la Grotte Gilvaran, niveau 5; récent *Capreolus capreolus* d'Espagne (MNCN); récent *Axis axis* (MNCN); *Dama dama geiselana* de Neumark Nord (LVH); récent *Rupicapra rupicapra* d'Espagne (MNCN); *Ovis* sauvage de l'Espagne (MNCN); *Capra pyrenaica* de la Sierra de Gredos (Espagne; MNCN).

Photographie: sésamoïdes axiaux, à l'arrière de la première phalange, du côté droite de l'axe du pied (figs 3-5), dans chaque cas: vue a) distale, b) latérale, c) dorsale, d) axiale, e) plantaire, et f) proximale. 1) GLV-AY1-35, niveau 5 - *Capreolus* de la Grotte Gilvaran 2) MNCN exemplaire sans numeró de la collection du département de paleobiologie - sésamoïde du pied de *Axis axis* 3) MNCN 21437 - sésamoïde de le pied de *Capreolus capreolus* de Otero del Valle (Espagne) 4) MNCN 18247 - sésamoïde de le pied *Capra pyrenaica* de the Sierra de Gredos (Espagne) 5) MNCN 14259 – sésamoïde de le pied de *Rupicapra pyrenaica* de Asturias (Espagne).



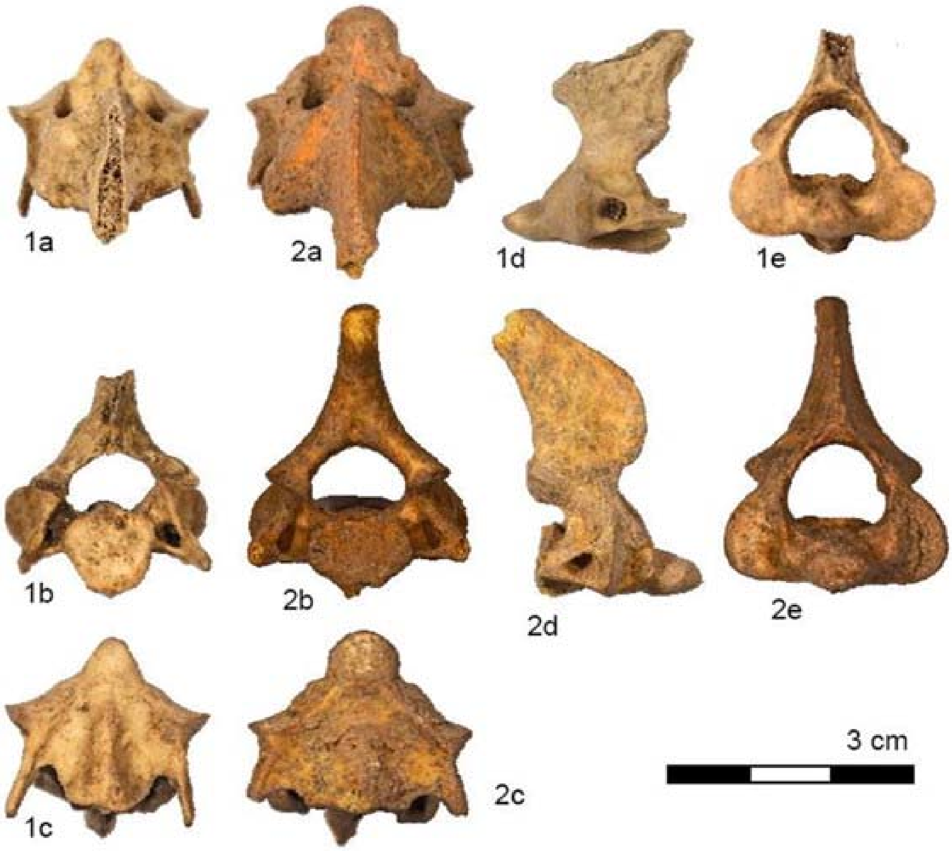
SOM Figure 11. Bivariate diagram of the first phalanx of: Ghamari Cave specimen GHM-17; recent *Axis axis* (MNCN, HUJ); *Dama dama geiselana* from Neumark Nord (LVH); *Cervus elaphus* from Neumark Nord (LVH) and Roter Berg (NMB); recent *Capra pyrenaica* (MNCN, IPHES); *Capra caucasica?*from Azykh V (MUB), Ortvala (GSM) and Sakazia (GSM); *Capra ibex* from Petralona (AUT); *Hemitragus bonali* from Hundsheim (IPUW).

Photographs: 1) KLD-12, level 5 - left $M^{1/2}$ of *Capra* from Kaldar Cave; buccal view 2) GLV-AY1-97, level 3 - left I_2 of *Capra* from Gilvaran Cave; a) lingual, b) mesial, c) labial, and d) distal views 3) GHM-17, level 4 - distal fragment of a first (or "proximal") phalanx from Ghamari Cave of cf. *Dama mesopotamica*; a) distal, b) axial, c) dorsal, d) abaxial, and e) abaxial views 4) KLD-20, level 4 - right I_3 of *Capra* from Kaldar

Cave; a) lingual, b) distal, c) labial, and d) mesial views 5) GHM-48, level 5 - left $M_{1/2}$ (M_2?) of *Capra* from Ghamari Cave; a) buccal, b) occlusal, and c) lingual views 6) KLD-10, level 5 - left $M_{1/2}$ (M_1?) of *Capra* from Kaldar Cave; a) buccal, b) occlusal, and c) lingual views. The scale bar represents 1.5 cm for figure 4 and 3 cm for the remaining figures.

SOM Figure 11. Diagramme â deux entrées de la première phalange de: Grotte Ghamari spécimen GHM-17; *Axis axis* récente (MNCN, HUJ); *Dama dama geiselana* de Neumark Nord (LVH); *Cervus elaphus* de Neumark Nord (LVH) et Roter Berg (NMB); *Capra pyrenaica* récente (MNCN, IPHES); *Capra caucasica?*de Azykh V (MUB), Ortvala (GSM) et Sakazia (GSM); *Capra ibex* de Petralona (AUT); *Hemitragus bonali* from Hundsheim (IPUW).

Photographie: 1) KLD-12, niveau 5 - $M^{1/2}$ gauche de *Capra* de Grotte Kaldar; vue buccale 2) GLV-AY1-97, niveau 3 - I_2 gauche de *Capra* de la Grotte Gilvaran; vue a) linguale, b) mesiale, c) labiale, et d) distale. 3) GHM-17, niveau 4 - fragment distal d'une phalange de la Grotte Ghamari de cf. *Dama mesopotamica*; vue a) distale, b) axiale, c) dorsale, d) latérale, et e) latérale. 4) KLD-20, niveau 4 - I_3 droite de *Capra* de la Grotte Kaldar; vue a) linguale, b) distale, c) labiale, et d) mesiale. 5) GHM-48, niveau 5 - $M_{1/2}$ (M_2?) gauche de *Capra* de la Grotte Ghamari; vue a) buccale, b) occlusale, et c) linguale. 6) KLD-10, niveau 5 - $M_{1/2}$ (M_1?) gauche de *Capra* de la Grotte Kaldar; vues a) buccale, b) occlusale, et c) linguale. L'échelle est de 1,5 cm à la figure 4 et 3cm pour les autres figures.



SOM Figure 12.

1) CENIEH O-75 - axis of *Hystrix cristata*; a) dorsal, b) posterior, c) ventral, d) left lateral, and e) anterior views. 2) GHM-F2-22, level 4 - axis of *Hystrix* from Ghamari; a) dorsal, b) posterior, c) ventral, d) right lateral, and e) anterior views.

SOM Figure 12.

1) CENIEH O-75 - axis de *Hystrix cristata*; vues a) dorsal, b) postérieure, c) ventrale, d) latéral gauche, et e) antérieure. 2) GHM-F2-22, niveau 4 - axis de *Hystrix* de Ghamari; vues a) dorsale, b) posterieure, c) ventrale, d) latérale droite, et e) antérieure.

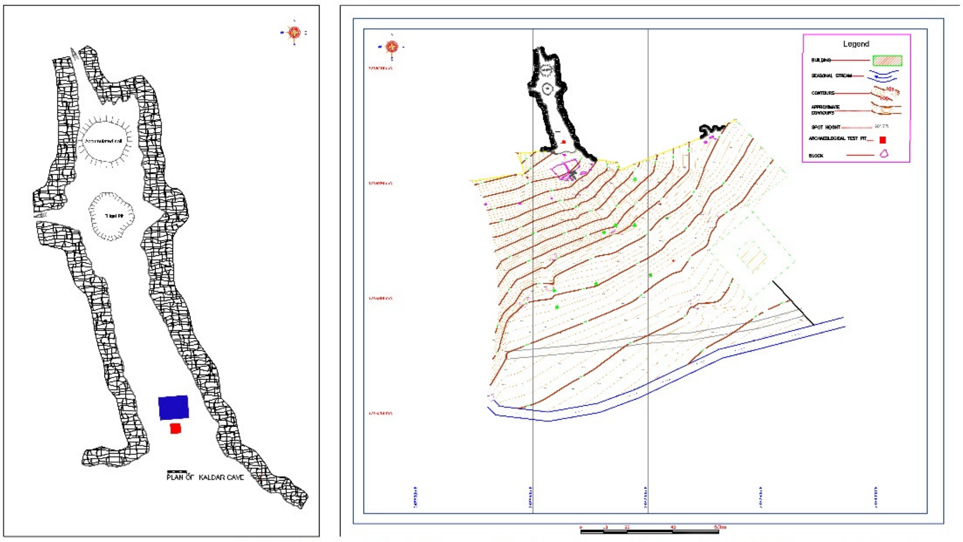
3-4: Excavation at Kaldar Cave (First and second season)

This cave is situated in the north of Khorramabad valley at 48◦:17_:35__E longitude, 33◦:33◦:25N latitude and 1290meters a.s.l. It is 16 m long, 17 mwide and 7 m high. In 2010, as a part of a comprehensive exploration of the Khorramabad Valley, along with a local team I realized the importance of this cave for excavation. As metioned in Bazgir et al. 2014, this cave was recorded in the list of Lorestan Cultural Heritage and Tourism Organization by Z. Bakhtiari. However, not being specialist in Paleolithic chronology, he estimated Epipaleolithic age for the Kaldar Cave. In my first visit to the site, I collected several flakes, cores, blades and bladelets, some showing main characteristic elements of Levallois and Baradostian technologies. In addition to that, its geographical position in the extreme north of the Khorramabad Valley, made me think to explore the fill of the cave.

Concerning geographical location of Kaldar Cave, all the previous studied and reported sites within the Khorramabad Valley come from its southern parts. With this scenario I decided to explore this cave as a new area of the valley and to investigate its cultural materials for comparision with the other sites in different geographical locations.

Another reason for selecting this locality for excavation was because of its suitable position, located in the Wild Life Century zone, that protects it from illegal excavation, a common problem with most of Khorramabad sites. With this in mind, after plotting and mapping the archaeological deposit of the site, we carried out a topographic drawing of the site and its outskirt area (Fig 3-4A & 3-4B).

Figure 3-4A: Plotting and mapping the site



Detailed topography with the exact location of excavated areas highlighted in red and blue color

Figure 3-4B: Topography of the site and its outskirt area. Location of the first test excavation is shown in red and the trench of the second excavation season in blue colour

3-4a: Stratigraphy and archaeological context

In both the excavation seasons (2011-12 & 2014-15) we recognized five major layers and several sub-layers which are described in details in Bazgir et al. 2014 and Bazgir et al. 2017. (In chapter 3, sub-chapter 3-3e, Publication 1 & in chapter 3, sub-chapter 3-4e, Publication 2 respectively).

3-4b: Lithic industry

Same as Gilvaran lithic assemblage, Kaldar shows a great diverse lithic industry with very well state of preservation of the artifacts within its stratigraphic sequence. The heavily retouched artifacts dominates its Mousterian assemblage. Moreover, Levallois flakes, blades and points and Mousterian points consist the major part of the Middle Paleolithic assemblage of Kaldar Cave. Presence of large number of points is crucial in the assemblage.

In the Upper Palaeolithic lithic assemblages of Kaldar Cave there is a considerable amount of bladelets and blades. The second large category of artifacts are the retouched pieces I the assemblage. Presence of Arjeneh points as a finger print for the Baradostian technology. A detailed technological analysis of the recovered lithic assemblage from Kaldar Cave is provided in Bazgir et al. 2014 and Bazgir et al. 2017, presented in this thesis. However, it is worth mentioning here that there is a significant technological change from flake towards the production of blades and bladelets technology. In addition to our comparative analysis results in Bazgir et al. 2017, we performed a more precise metric analysis using more measurable elements to find out the possible evolutionary continuation from Mousterian to Baradostian technology within the recovered assemblage. A detailed information on those analysis is presented in the forthcoming chapter 4.

3-4c: Faunal remains

A list of identified taxa or anatomical parts of the recovered faunal remains is given below.

***Equus* sp.**

An incisor was found in Layer 4 (sub-layer 5 II). It is a large one, suggesting that it belonged to a caballoid horse and not to the smaller *E. hydruntinus* or *H. hemionus*. The specimen was figured by Bazgir et al. (2015, figure S11/2) and assigned to *Equus* sp.

Sus scrofa

A canine of a male suid from layer 4 was figured by Bazgir et al. (2014, figure 8/1) and assigned to *S. scrofa*. It has a "scrofic" section, with the posterior side wider than the labial side, while canines with a "verrucose" section have the posterior side narrower than labial side. This is typical of *Sus scrofa*, while most other Pleistocene pigs have canines with "verrucose" sections, save for the very small *Sus salvanius*.

***Capreolus* sp.**

A first (or "proximal") phalanx was figured by Bazgir et al. (2014, figure S1) and assigned *Capreolus* sp. Its size and proportions are different from other small ruminants that might be expected, such as *Gazella*. It is larger than in the living species *C. capreolus*. The presence of this small deer was confirmed by posterior finds, including a tooth fragment in which the crests are arranged as in cervids and unlike in bovids.

Cervus elaphus

A fragment of the tip of an antler with a length of 3 cm was figured by Bazgir et al. (2014, figure 8/3) and assigned to Cervidae indet. cf. *Cervus elaphus*. In the 2014 campaign more finds of this species were made, including the upper canine of a female, which allowed to assign the material without reservation to *Cervus elaphus* (Bazgir et al., 2017, figure S11/1).

Bovini indet.

A distal tibia from level 5 with the morphology of a bovid or cervid and the size of a bovine, suggests the presence of such an animal.

Caprini indet. cf. *Capra aegagrus*

Dental and postcranial remains indicate the presence of a goat in layers 5 and 7. A lower third molar was figured and assigned to *Capra* sp. cf. *C. aegagrus* (Bazgir et al., 2017, figure S11/3).

Crustacea indet.

The presence of a crab is indicated by a pincer of a crab, which has been figured by Bazgir et al. (2014, Figure 8/5). The greatest length of the fragment is 12.8 mm. Crabs tend to live in or near water and the find suggests that water was nearby and that either the crab entered the cave or that a human or another predator brought the pincer into the cave.

Detailed description and position in global context have been given in Bazgir et al. 2014 and Bazgir et al. 2015.

3-4d: Functional studies

As mentioned in the sub-headings (3-1e and 3-2d),as a part of ongoing multidisciplinary studies, we carried out a comprehensive documentation of macro and micro fractures, usewear and residues, using Optical Light Microscope (Zeiss Aixo Scope A1) and Digital 3D Hirox microscope. As mentioned earlier, our preliminary observation indicates that, among all the excavated sites, Kaldar assemblage shows a much better preservation of both usewear and residues. Other localities, mainly Gilvaran assemblage provide more usewears and fewer residues. Here there are several examples of macro fractures, usewear and residues (Figs 3-4dA to 3-4dX).

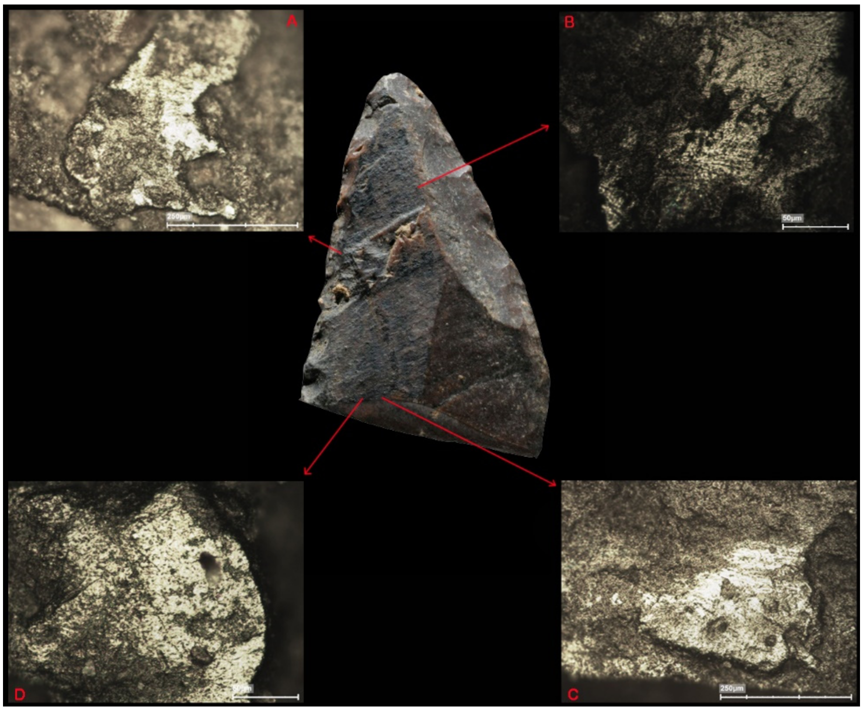


Figure 3-4dA: Polish along with striations on different parts of a retouched Levallois point, positions indicated by arrows. (Middle Paleolithic-Layer 5).

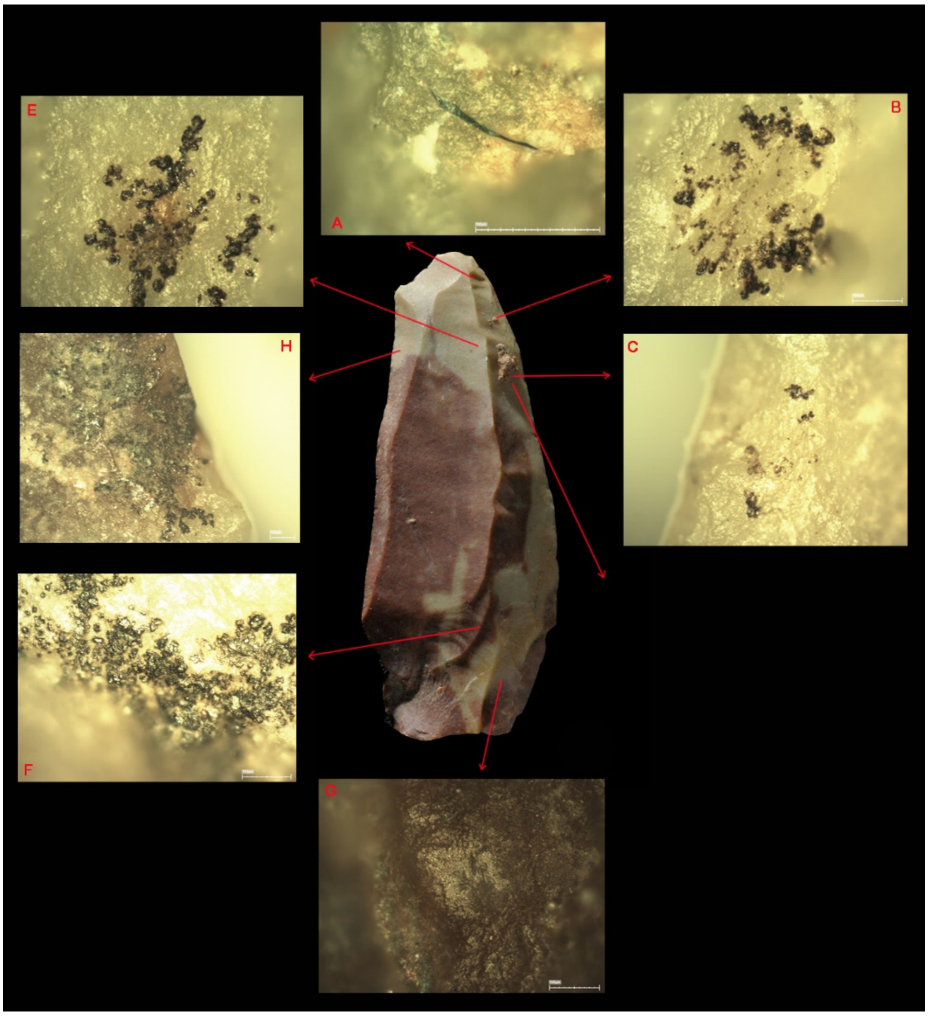


Figure 3-4dB: Polish on proximal portion and several black residues on different parts of a Levallois point, positions are indicated by arrows. (Middle Paleolithic-Layer 5).

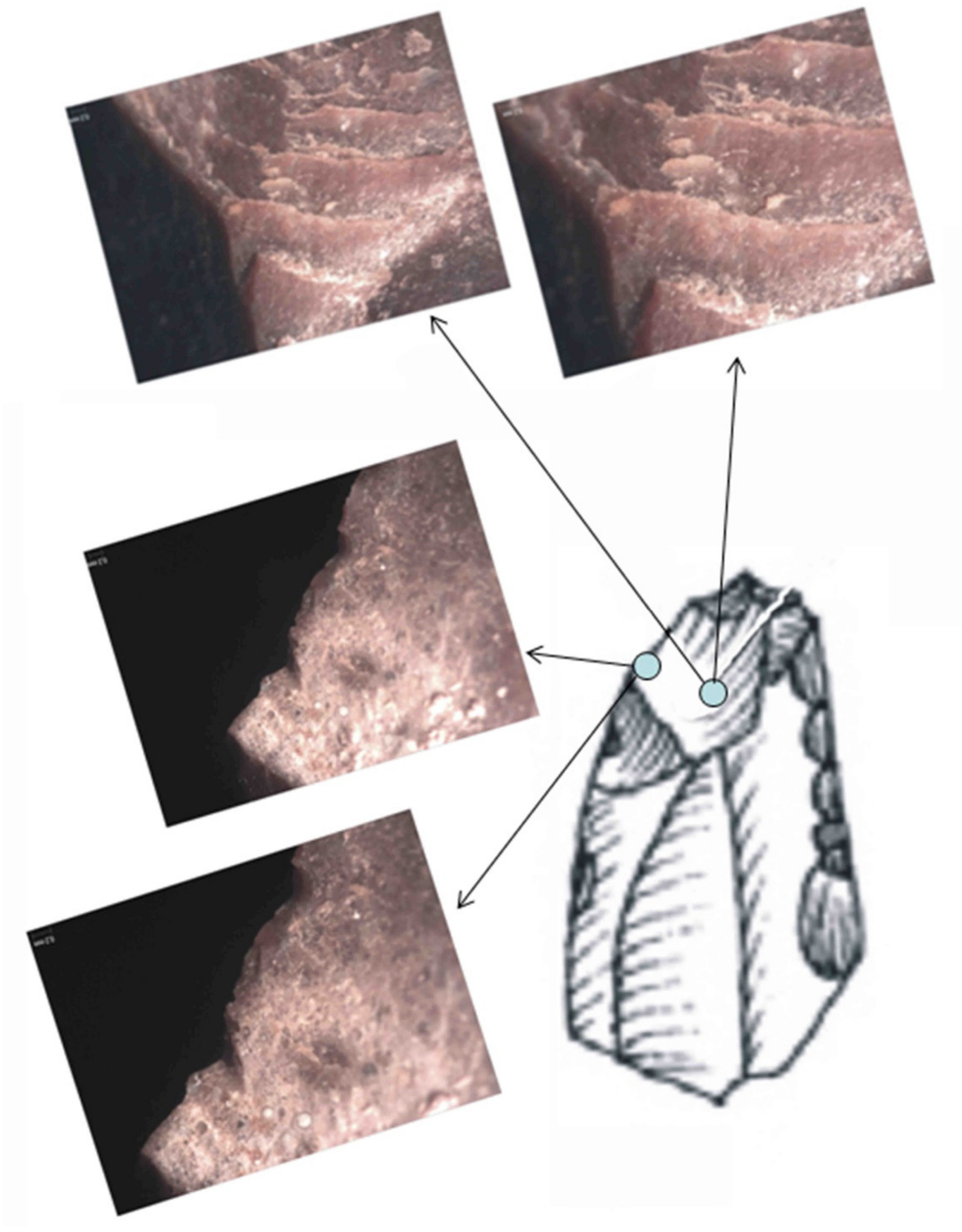


Figure 3-4dC: Macro fracture on distal part of aretouched Levallois point (Middle Paleolithic-Layer 5).

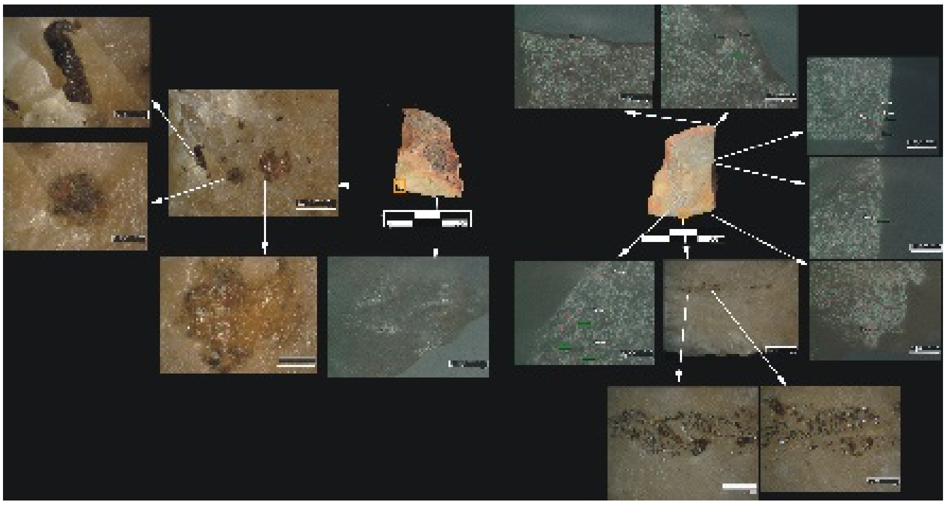


Figure 3-4dD: On the dorsal side, polish and different color residues are mostly concentrated on the distal part and on ventral side, striations (diagonal as well as parallel to the edge) and polishes can be seen on the distal, proximal and on the left side of the medial part of the cortical flake. (Upper Paleolithic-Layer 4).

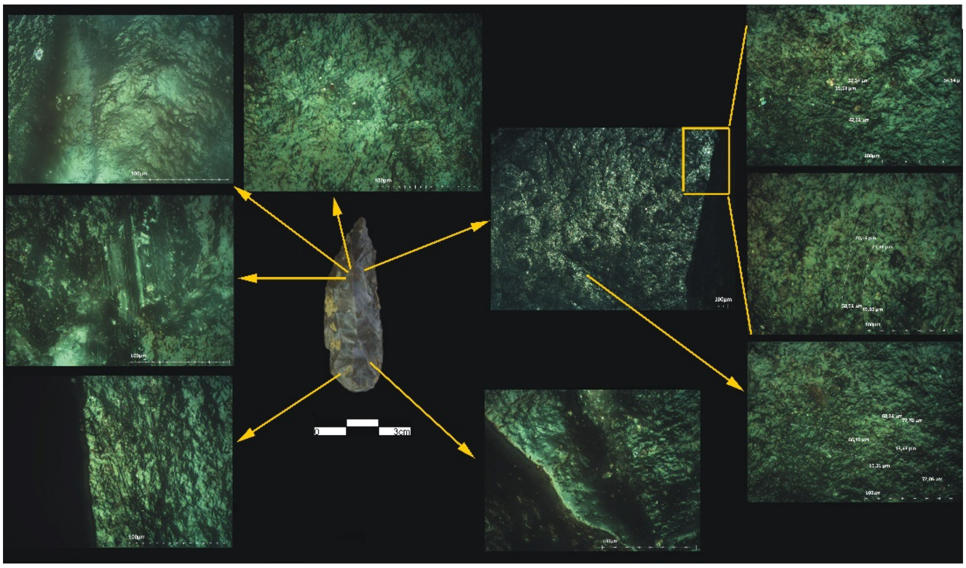


Figure 3-4dE: On the dorsal side, parallel as well as criss-cross striation can be seen on the distal part and heavy polish is present on the proximal end of the Arjeneh point (Upper Paleolithic-Layer 4).

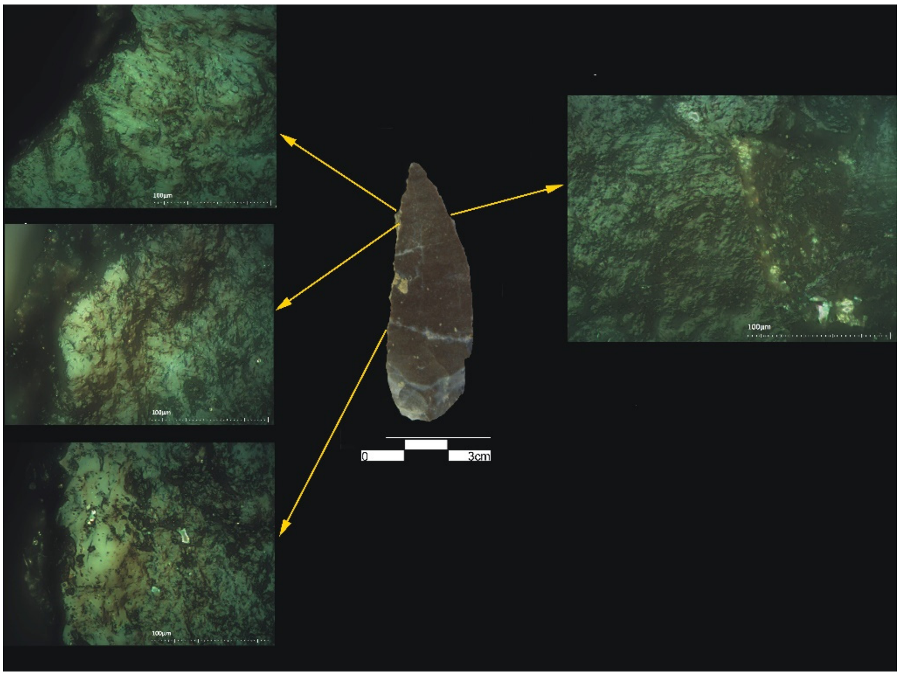


Figure 3-4dF: On the ventral side, heavy polish is present on the right distal to medial part and vertical striations on the left medial part of the Arjeneh point (Upper Paleolithic-Layer 4).

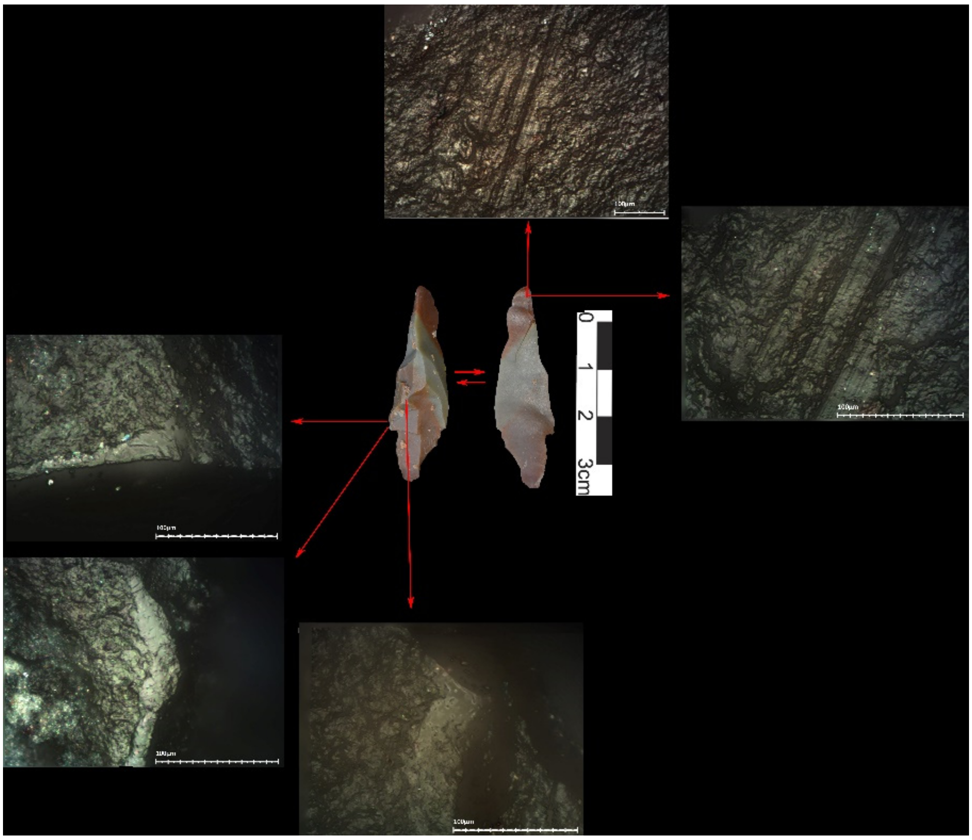


Figure 3-4dG: Heavy and deep striations on the distal part and scaring and polish on the proximal part of the pointed bladelet (Upper Paleolithic-Layer 4).

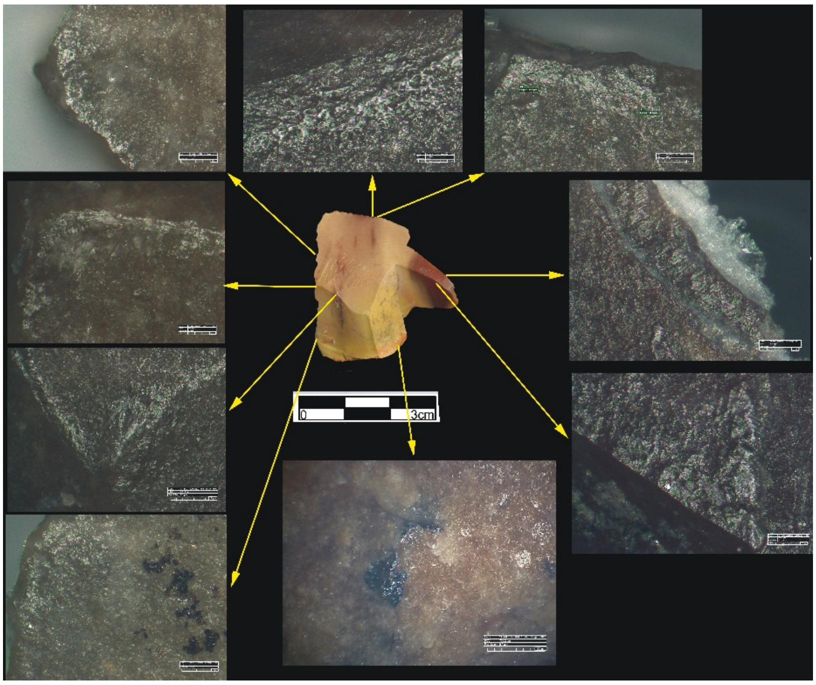


Figure 3-4dH: On the dorsal side of KLD-E7-5-276, heavy polish from the distal left side to proximal end along with edge rounding. Striations on distal right and black residues on the proximal part of the cortical flake (Upper Paleolithic-Layer 4).

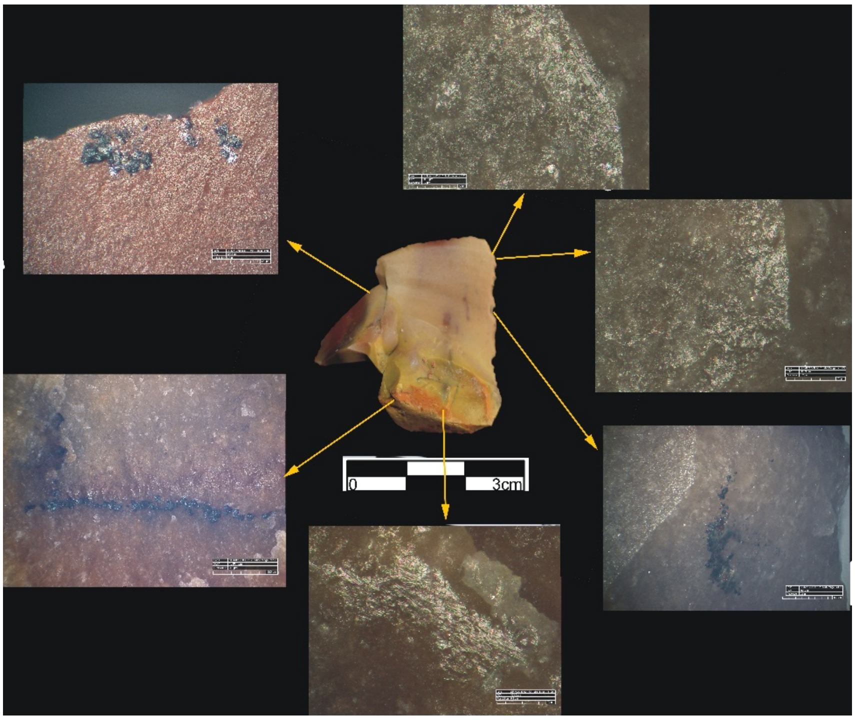


Figure 3-4dI: on the ventral side of KLD-E7-5-276, polishes on the right distal and proximal part of the lithic. Black residues are present on the both side edges of the cortical flake (Upper Paleolithic-Layer 4).

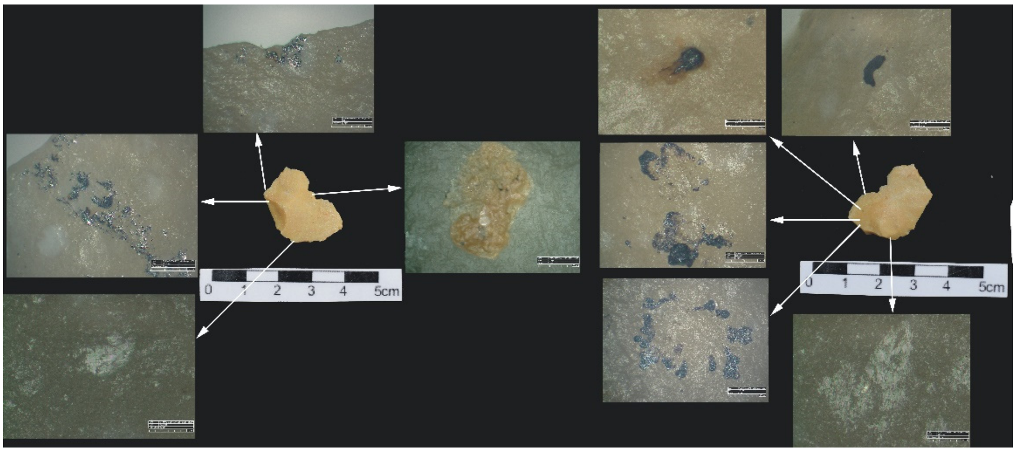


Figure 3-4dJ: polish on the proximal part on the both dorsal and ventral side. Black and cream colour residue on the medial and proximal part of the blade the cream colour residue under micro X-Ray diffraction analysis confirming of hydroxyapatite means bone residue. (Upper Paleolithic-Layer 4).

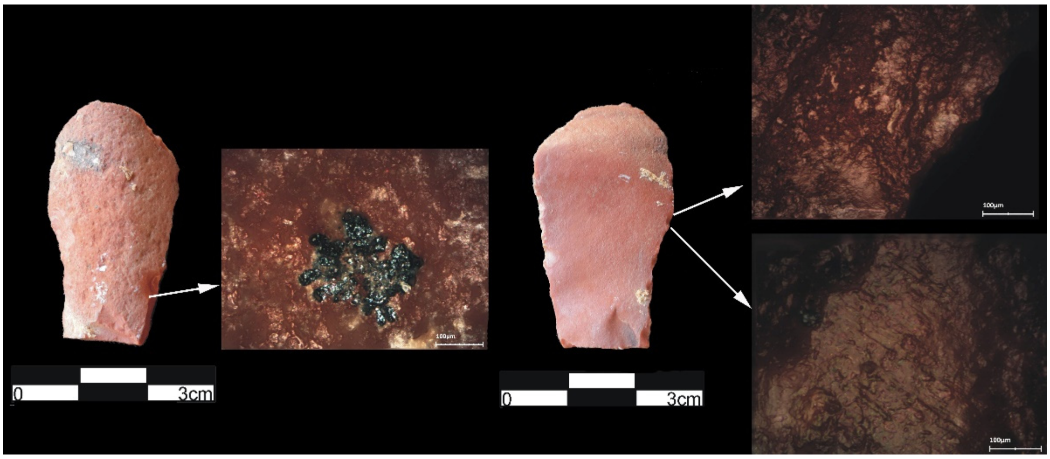


Figure 3-4dK: black residue on the right proximal part and slight polish in patches and vertical striations on the medial right part of the cortical blade. (Upper Paleolithic-Layer 4).

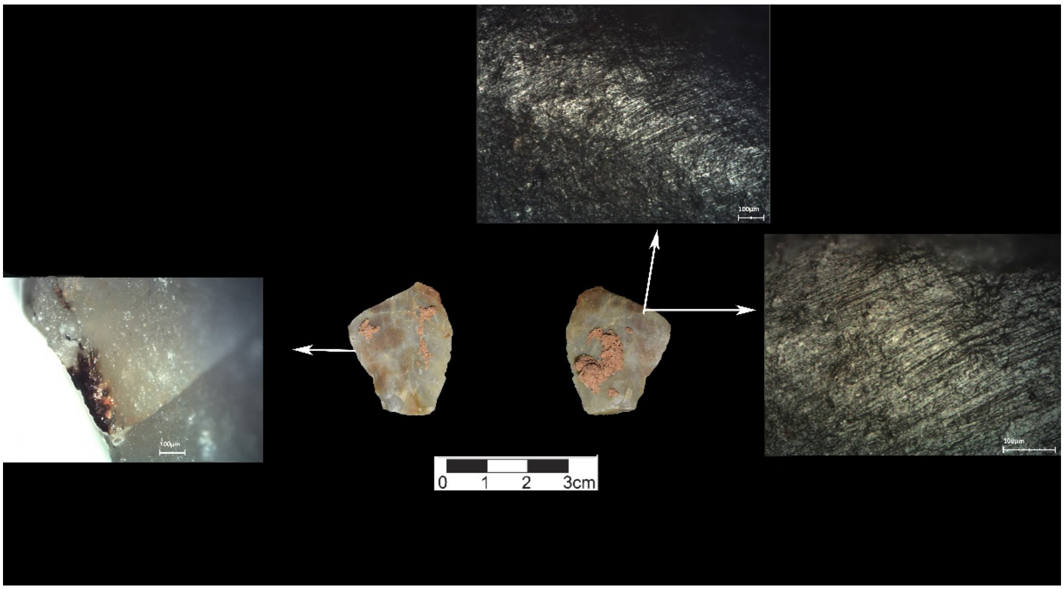


Figure 3-4dL: black residue on the left medial part and heavy, and well developed polish with tranverse striations parallel to each other on the distal part of the flake (Upper Paleolithic-Layer 4).

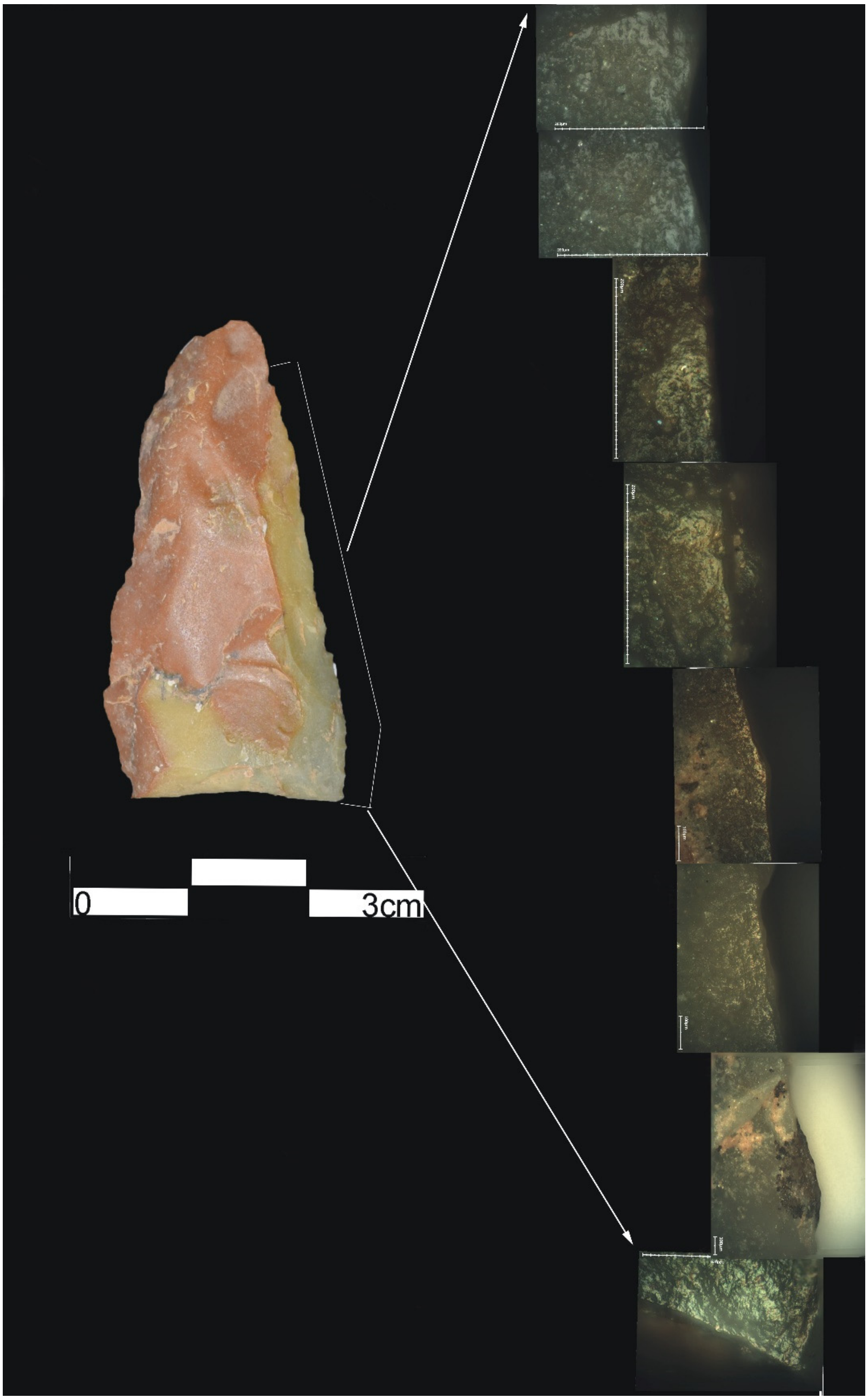


Figure 3-4dM: on the dorsal side of KLD-E6-5II-906, continuous polish and edge rounding on the right side of the lithic. Black residues are present on the proximal right side and few diagonal striations on the medial right side of the pointed cortical blade (Upper Paleolithic-Layer 4).

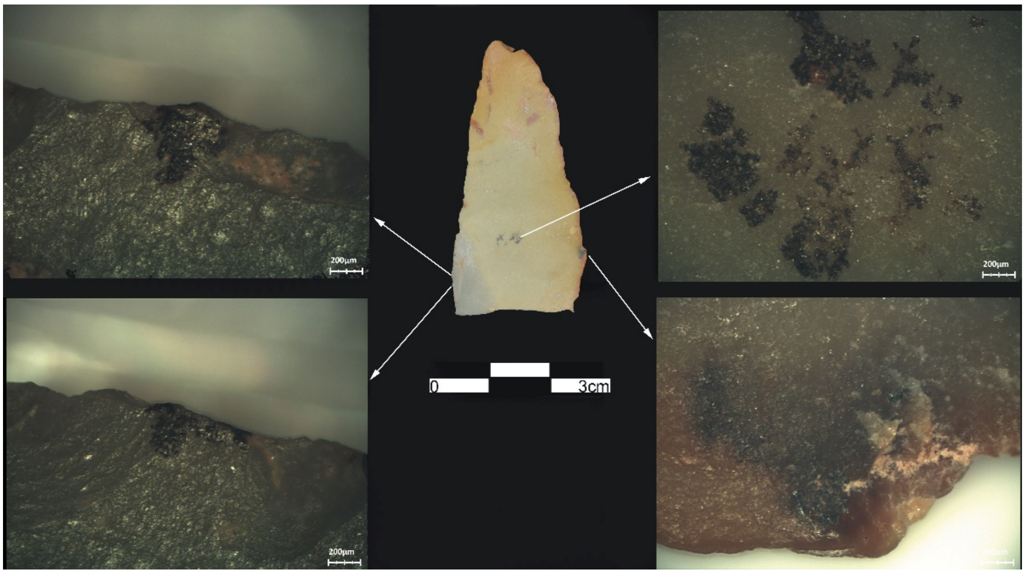


Figure 3-4dN: on the ventral side of KLD-E6-5II-906, black residues are present on the proximal part of the pointed cortical blade (Upper Paleolithic-Layer 4).

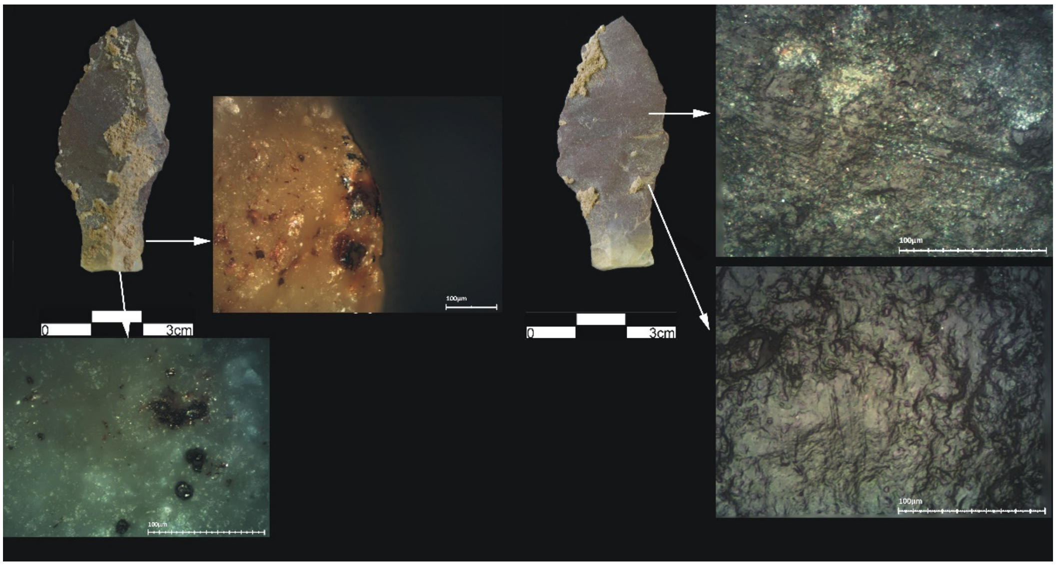


Figure 3-4dO: on the dorsal side, black residues are present on the proximal right side and on ventral side, vertical and horizontal striations on the medial right side of the Tanged point (Upper Paleolithic-Layer 4).

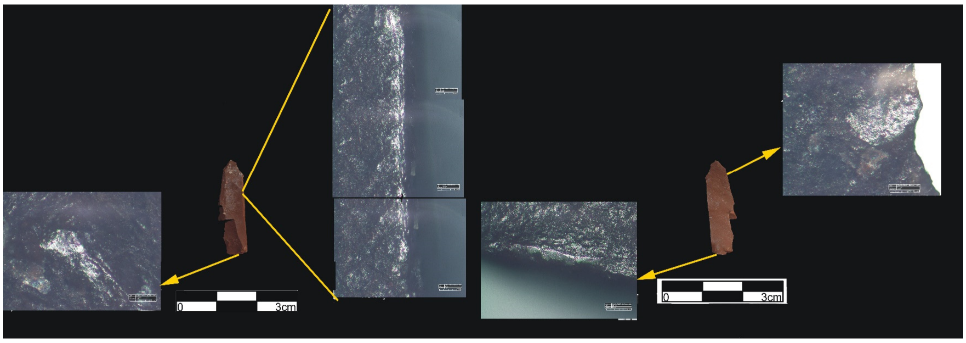


Figure 3-4dP: on the dorsal side, polish are present on the distal and proximal right side and on ventral side, polish is on distal and proximal part of the bladelet (Upper Paleolithic-Layer 4).

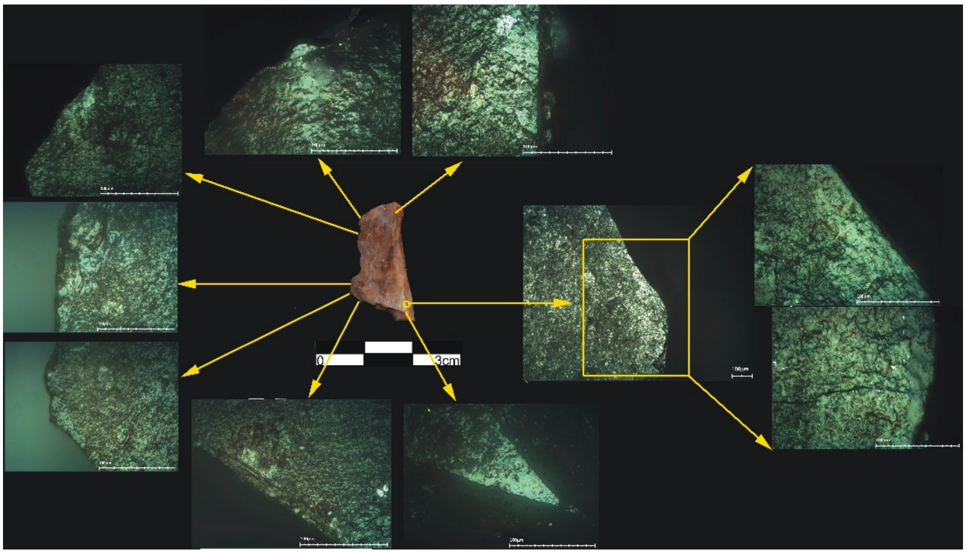


Figure 3-4dQ: polish and scar polish on the distal and proximal part of the broken blade (Upper Paleolithic-Layer 4).

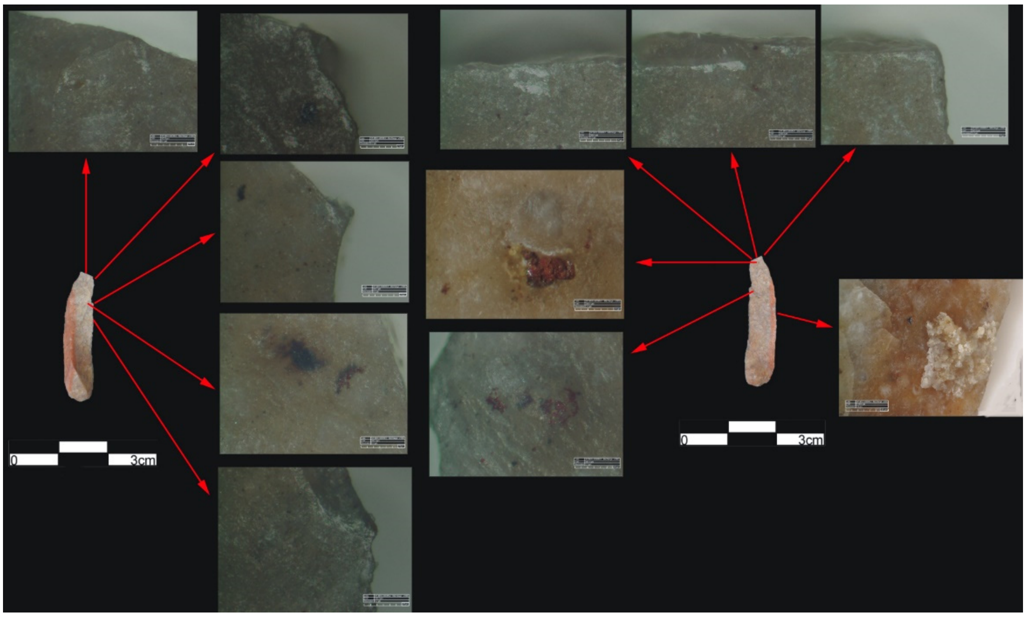


Figure 3-4dR: polish in patches on the distal part on both dorsal and ventral side. Red residue on the dorsal right and black residue on the ventral left side of the pointed bladelet (Upper Paleolithic-Layer 4).

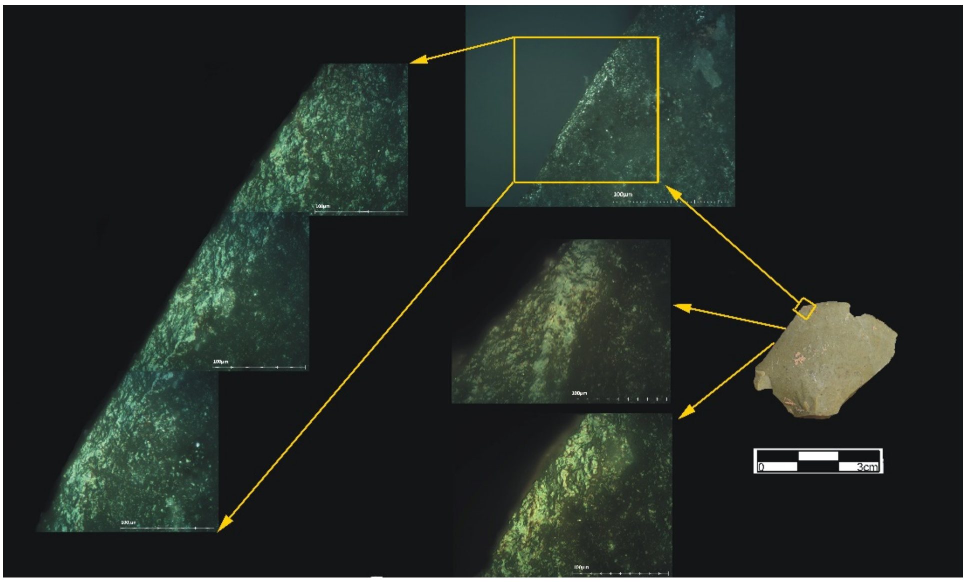


Figure 3-4dS: on the dorsal side of KLD-E5-5-180, continuous polish from distal to medial left part of the cortical flake. (Middle Paleolithic-Layer 5).

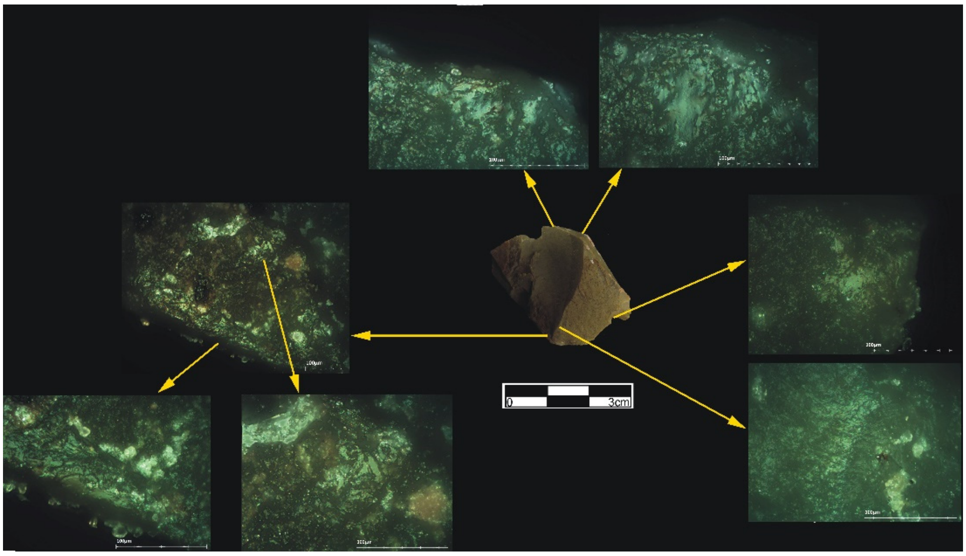


Figure 3-4dT: on the ventral side of KLD-E5-5-180, scar polishes on the distal and proximal part of the cortical flake. (Middle Paleolithic-Layer 5).

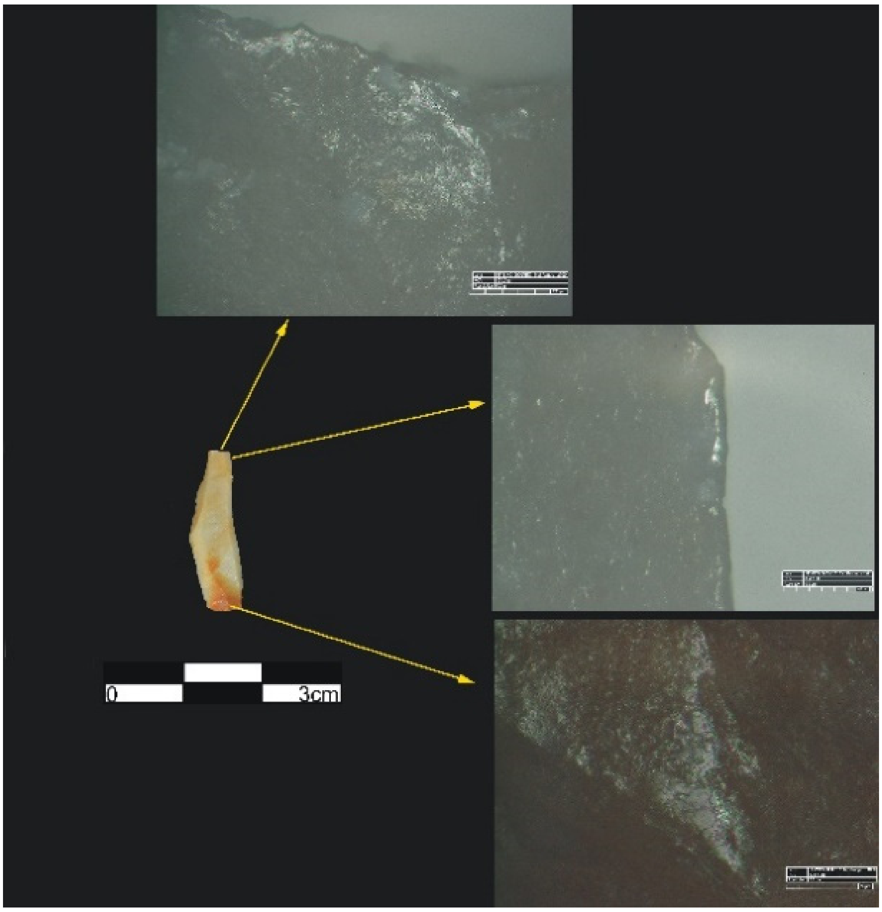


Figure 3-4dU: polish and edge rounding on the distal right and proximal part of the bladelet (Upper Paleolithic-Layer 4).

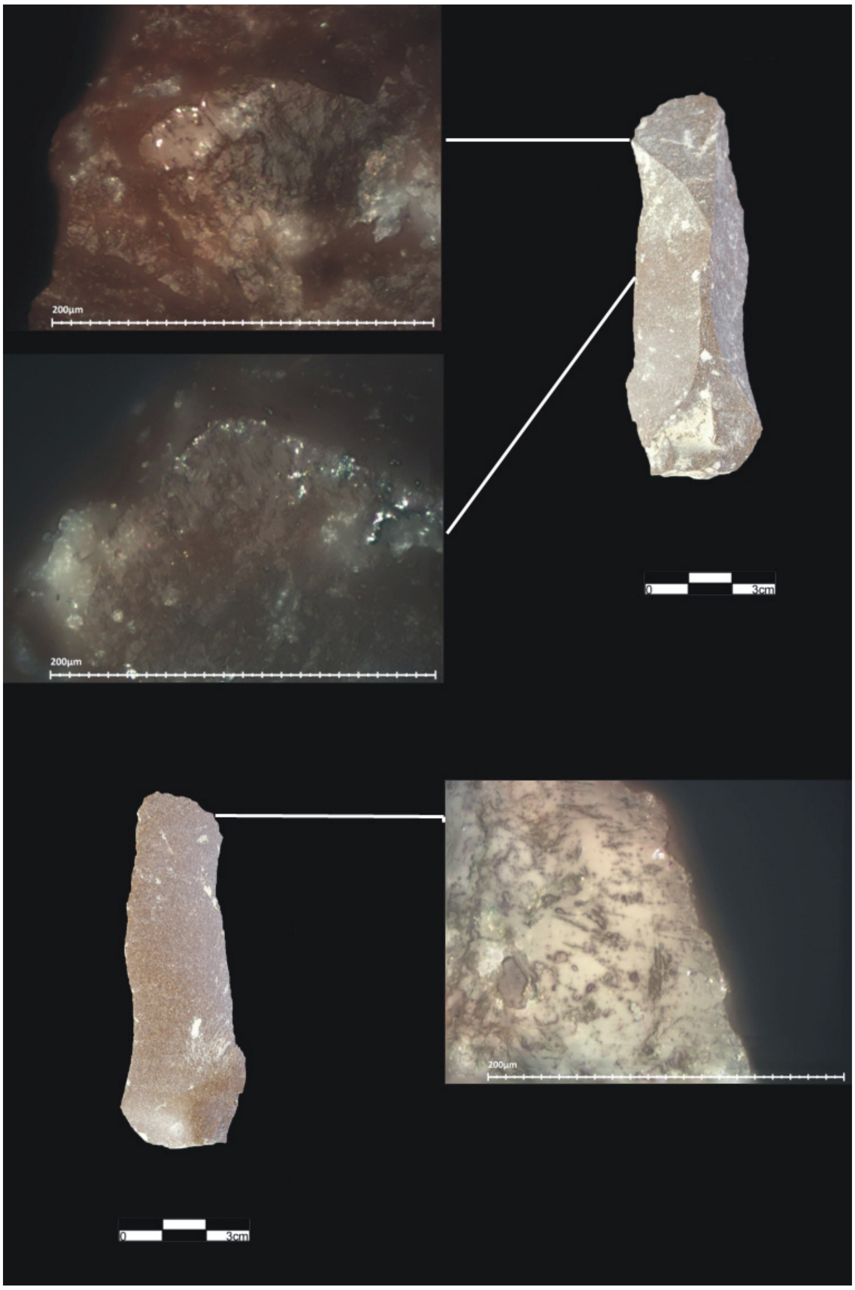


Figure 3-4dV: the dorsal side slight polishes on the left distal part and on ventral heavy polish on the distal right part of the elongated blade. (Upper Paleolithic-Layer 4).

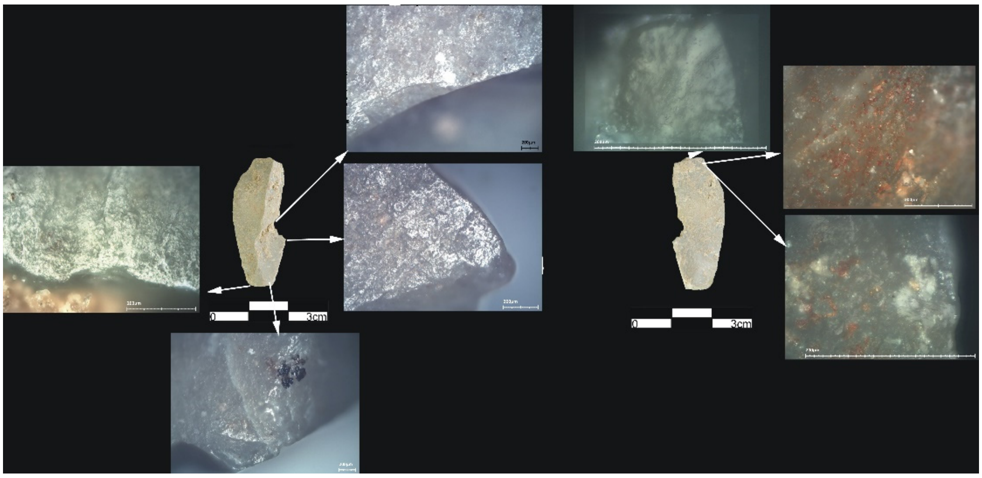


Figure 3-4dW: on the dorsal side, heavy polishes on the medial right and proximal part with a black residue. On the ventral side, heavy polish on the distal end and red residue on the elongated retouched blade. (Upper Paleolithic-Layer 4).

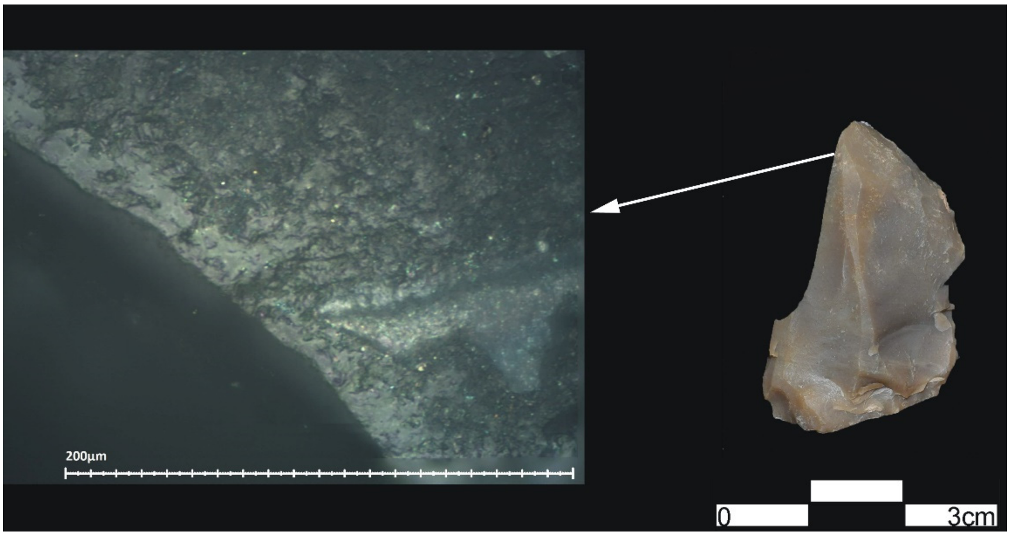


Figure 3-4dX: polish on the left distal part of the broken retouched point. (Middle Paleolithic-Layer 5).

3-4e: Publication 2

Bazgir B, Ollé A, Tumung L, Becerra-Valdivia L, Douka K, Higham T, van der Made J, Picin A, Saladié P, López-García JM, Blain HA, Allué E, Fernández-García M, Rey-Rodríguez I, Arceredillo D, Bahrololoumi F, Azimi M, Otte M, Carbonell E. 2017. Understanding the emergence of modern humans and the disappearance of Neanderthals: Insights from Kaldar Cave (Khorramabad Valley, Western Iran). Scientific Reports. 7:43460 | DOI: 10.1038/srep43460

In this publication, we presented a detailed description of the newly excavated stratigraphy of Kaldar Cave, quantified results from the lithic assemblages, preliminary faunal remains analyses, geochronologic data, taphonomic aspects, and an interpretation of the regional paleoenvironment.

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Understanding the emergence of modern humans and the disappearance of Neanderthals: Insights from Kaldar Cave (Khorramabad Valley, Western Iran)

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Kaldar Cave is a key archaeological site that provides evidence of the Middle to Upper Palaeolithic transition in Iran. Excavations at the site in 2014–2015 led to the discovery of cultural remains generally associated with anatomically modern humans (AMHs) and evidence of a probable Neanderthal-made industry in the basal layers. Attempts have been made to establish a chronology for the site. These include four thermoluminescence (TL) dates for Layer 4, ranging from 23,100 ± 3300 to 29,400 ± 2300 BP, and three AMS radiocarbon dates from charcoal samples belonging to the lower part of the same layer, yielding ages of 38,650–36,750 cal BP, 44,200–42,350 cal BP, and 54,400–46,050 cal BP (all at the 95.4% confidence level). Kaldar Cave is the first well-stratified Late Palaeolithic locality to be excavated in the Zagros which is one of the earliest sites with cultural materials attributed to early AMHs in western Asia. It also offers an opportunity to study the technological differences between the Mousterian and the first Upper Palaeolithic lithic technologies as well as the human behaviour in the region. In this study, we present a detailed description of the newly excavated stratigraphy, quantified results from the lithic assemblages, preliminary faunal remains analyses, geochronologic data, taphonomic aspects, and an interpretation of the regional paleoenvironment.

Understanding the initial spread of anatomically modern humans (AMHs) out of Africa is a key goal for palaeoanthropologists. AMHs originated in Africa and spread across the Middle East into Eurasia and towards Australia and the Americas. These AMHs were the first humans to occupy the latter two continents, but they replaced

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other populations in Eurasia. Because few well-dated human remains are available to study this dispersal process, the spread of AMHs is best documented by the appearance of the early phase of their culture, inferred to be the Aurignacian (but see ref. 1). In western Eurasia, this technocomplex replaced the Mousterian, associated in this region with Neanderthals. This transition may have occurred at approximately 50 to 40 ka (see refs 2–7).

One key area relevant to the dispersal process is Iran and Iraq, particularly the Zagros Mountains. Since the first survey of the Zagros by D. Garrod in 1930, Palaeolithic deposits and surface finds have been reported from a large number of caves, rockshelters, and open-air sites, but few of them have been fully excavated. Locally, the early phase of the technocomplex associated with early AMHs is known as the Baradostian. The early Upper Palaeolithic assemblages are also known as the Rostamian, which is defined as a bladelet-based technocomplex[8–11]. Although Conard et al. view the Rostamian as an industry distinct from the Baradostian[11], both terms refer to the early Upper Palaeolithic in the Zagros region.

Many of the researchers who study materials from the Zagros agree that the lithic assemblages from this region share some features with assemblages from central Europe and the Levant. These include typo-technological characteristics of the Aurignacian tradition as well as inter-assemblage variability[12–14]. Olszewski and Dibble[12], for example, proposed changing the name of the Baradostian to the 'Zagros Aurignacian' in light of the perceived similarities with Aurignacian material.

There is disagreement, however, regarding whether the Upper Palaeolithic evolved from earlier Mousterian industries in the region[15]. Some authors have proposed that the Baradostian might have developed locally from the Mousterian[5,12–14,16–32]. On the one hand, recent work on two stratified assemblages from Warwasi and Yafteh support an *in situ* evolution of the Upper Palaeolithic from the local Mousterian[15]. That study, however, focused on only two assemblages; thus, the conclusions might not be fully applicable to the entire Zagros region. On the other hand, Tsanova[15] raised doubts about whether the Iranian Zagros was the source of bladelet technology. However, the discovery of over 90 sites in the southern Zagros mostly associated with bladelet-based technologies—one of which dates to 40,000 cal. BP—suggests that the technology in the region featured a high degree of complexity[5,8–11].

Additionally, the Zagros is more than 2,000 km long from northwest to southeast and up to several hundred kilometres wide from east to west[27]. Due to the lack of extensive surveys and archaeological excavations in the region, many aspects remain poorly understood. The latest typo-technological analyses on the lithic assemblage from the site of Ghar-e-Khar, for example, indicate the presence of multiple sites containing both Middle and Upper Palaeolithic sequences in the Zagros region. These findings confirm the potential for continued research into the Middle to Upper Palaeolithic transition[33]. However, only a few excavated sites contain uninterrupted archaeological sequences that include both Middle and Upper Palaeolithic deposits[34]. Some well-excavated sites, e.g., Yafteh, do not have Middle Palaeolithic occupation levels. Besides the reported sites in the Gilvaran and Ghamari caves[35], Warwasi and Ghar-e-Khar are the only sites in the Iranian Zagros containing cultural remains belonging to both the Middle and Upper Palaeolithic (Fig. 1). To date, however, neither has been dated. Warwasi and Ghar-e-Khar were coarsely excavated (20 cm spits in Warwasi and 10–30 cm spits in Ghar-e-Khar). Chronometric control of the sites has been hampered by the poor preservation of organic material extracted from the archaeological sites and by political challenges and instability, which have made excavation work virtually impossible for more than 20 years. Here, we present the recently excavated and dated well-stratified sequence of Kaldar Cave, which documents the transition from the Middle to the Upper Palaeolithic.

Results

Site stratigraphy. Kaldar Cave is situated in the northern Khorramabad Valley at 48° 17′35″E longitude, 33°33′25″N latitude, and an elevation of 1,290 m above sea level. It is 16 m long, 17 m wide, and 7 m high. The potential of this site for excavation was first realized during a survey in 2010, when we started our regional study of the Khorramabad Valley as a goal-oriented research project. The first excavation[35] was conducted in 2011–12.

The 2014–15 excavation focused on gaining a better understanding of the stratigraphy and obtaining samples for dating. We opened a 3 × 3 m trench near the entrance and kept a 50 cm bulk sample from the previous test pit (squares E5, E6, E7, F5, F6, F7, G5, G6 and G7) (Supplementary Fig. S1). The excavation was conducted using spits of 5 cm within each archaeostratigraphic unit, as well as 3D recording of all findings.

The excavated trench exposed an approximately 2-m (195-cm) section of the sedimentary deposit, which is characterized by five main layers. During fieldwork, distinctions within the layers were made according to minor sedimentological differences. Ongoing microstratigraphic research will provide a proper characterization of the sub-layers.

Layers 1 to 3 (including sub-layers 4 and 4II) consist of ashy sediment with a blackish-green colour containing both thick and thin angular limestone clasts. These layers varied in thickness from 60 to 90 cm and contained many phases dating to the Holocene: the Islamic and historical eras, Iron Age, Bronze Age, Chalcolithic, and Neolithic. However, due to the presence of some bioturbation in these layers, the phases were recognized only by a preliminary study of the potsherds, metal artefacts and some diagnostic lithic artefacts from the lower layers.

Layer 4 (including sub-layers 5, 5II, 6 and 6II) consists a silty but compact dark-brown sediment with cultural remains from the Upper and early Upper Palaeolithic. In the uppermost parts of this layer, two fireplaces made of clay were recovered and dated through thermoluminescence, yielding ages that ranged from 23100 ± 3300 to 29400 ± 2300 BP (Table 1). The dates obtained show that these fireplaces were made or re-used from existing older sediment from the upper part of this layer in the later stages of the Upper Palaeolithic. AMS radiocarbon dates of 38650–36750 cal BP, 44200–42350 cal BP, and 54400–46050 cal BP have been obtained from charcoal material located below this layer (Table 2).

Layer 5 (including sub-layers 7 and 7II) consists of an extremely cemented reddish-brown sediment with some small angular limestone blocks and Middle Palaeolithic artefacts (Figs 2a,b and 3). To date, no radiometric data are available for this layer.

Figure 1. The excavated sites containing Middle Palaeolithic and early Upper Palaeolithic sequences in the Zagros. (Source of the original map: https://commons.wikimedia.org/wiki/File:Iran_relief_location_map.jpg (under the license of Creative Commons Attribution-Share Alike 3.0 Unporte). Modified by B. Bazgir. Original license pages: https://en.wikiedia.org/wiki/Creative Commons - https://creativecommons.org/licenses/by-sa/3.0/deed.en.

Sample	Specifications	Th	Ur	K2%	Equivalent Dose (ED)	Age
1	Layer 4: sub-layer 5, E6-7	1.76	3.95	0.81	73.64	26025 ± 2002
2	Layer 4: sub-layer 5, E6-7	2.94	1.86	0.97	51.97	29400 ± 2300
5	Layer 4: sub-layer 5, E6-7	2.46	5.54	1.29	178.79	25500 ± 2500
4	Layer 4: sub-layer 5, E5	1.51	3.30	1.19	64.85	23100 ± 3300

Table 1. List of thermoluminescence dating results from Kaldar Cave.

Sample	OxA-	Archaeological context	$\delta^{13}C$ (‰)	Conventionl radiocarbon age (BP)	Calibrated date (95.4% probability)
723	32238	Trench (T) 1; Layer 4, sub-layer 5; SQ E6; 69 (X), 12 (Y), 110 (Z)	−23.0	33,480 ± 320	38650–36750 cal BP
—	32239	T1; Layer 4, sub-layer 5; SQ G6	−23.1	964 ± 26	1000–1200 AD
—	32240	T1; Layer 5, sub-layer 7II; SQ F7	−27.1	1.09665 ± 0.00323**	1850–1950 AD
274	X-2645-11	T 1; Layer 4, sub- layer 5; SQ E7; 78 (X), 5 (Y), 85 (Z)	−23.4	39,300 ± 550	44200–42350 cal BP
869	X-2645-12	T1; Layer 4, sub-layer 5II; SQ E6; 45 (X), 100 (Y), 125 (Z)	−24.5	49,200 ± 1800	54400–46050 cal BP

Table 2. Radiocarbon results for charcoal samples from Kaldar Cave.

Bioturbation or disturbance was plotted, and sediment associated with the disturbance was removed without coordinating the finds, which were recorded as general finds with their approximate depths. Isolated evidence for intrusion below the Holocene layers was identified in a deep pit in square E7 in the upper part of the junction of sub-layers 5 and 5II. In the remainder of the site's sequence, these layers are extremely hard and contain no evidence of bioturbation or disturbance. Heavy hammers and chisels were necessary to excavate these deposits (Supplementary Fig. S2). Consequently, we reached bedrock only in squares E6, E7, F6 and F7 (Supplementary Fig. S3).

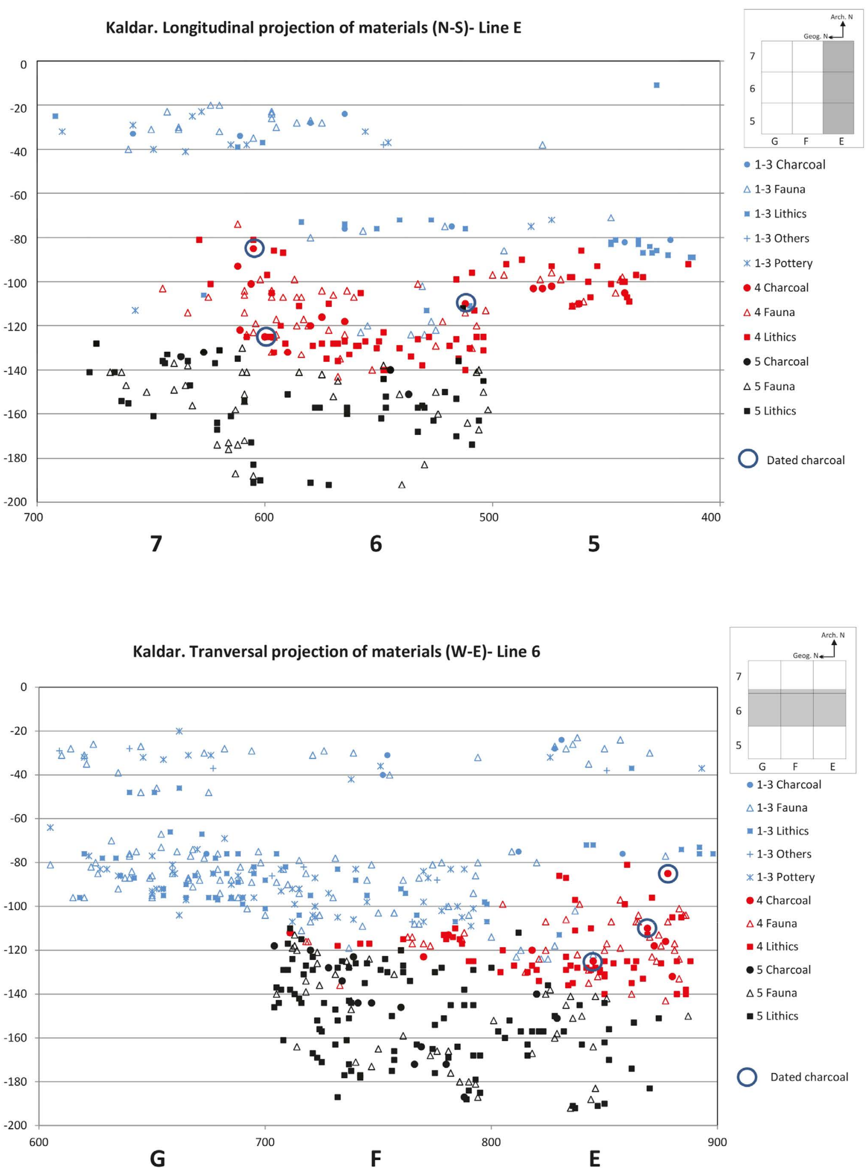

Figure 2. (**a**) North-south longitudinal projection of the materials from squares in line E. (**b**) West-east transversal projection of the materials from squares in line 6. Materials from Layers 1 to 3 have been projected together (blue). Projected separately are the materials from Layer 4 (red) and Layer 5 (black). Created by A. Ollé and B. Bazgir.

Faunal and floral remains. Bioarchaeological remains recovered to date allow us to make some initial environmental inferences and to correlate the faunal and the lithic records to reconstruct human subsistence activities.

A small portion of the faunal assemblage from Kaldar Cave was previously described[35], but the recent excavations have yielded new material—some of which is described in the supplemental information (Supplementary Information, Supplementary Fig. S11). The preliminary study of the small vertebrates from Kaldar Cave has identified 218 remains coming from Layer 4 (sub-layer 5II) and Layer 5 (sub-layer 7II), comprising rodents, squamate reptiles, and amphibians. The updated faunal list is given in Table 3. There is no indication of a faunal change coincident with the cultural change from Layer 5 to Layer 4.

Most of the amphibians and reptiles (Agamidae, *Eryx* and Elapidae) live in savannah, steppe and desert environments and feature lifestyles linked to warm arid areas in rocky or sandy environments. *Pseudopus* lives in dry and bushy environments, sometimes in open woodlands, but avoids dense forest areas. The two most abundant rodent species in both Layers 4 and 5 are *Microtus* gr. *socialis* and *Meriones* spp., indicating that the environment surrounding the cave was composed mainly of dry open areas, with some vegetation cover, as indicated by the presence of Gliridae and Murinae taxa in both layers. *Cervus elaphus*, *Sus scrofa* and *Capreolus* may have preferred the more closed and humid environments in the valley near the river, whereas *Equus* may have favoured more open environments somewhat farther away on the flood plain (which could not have been very wide).

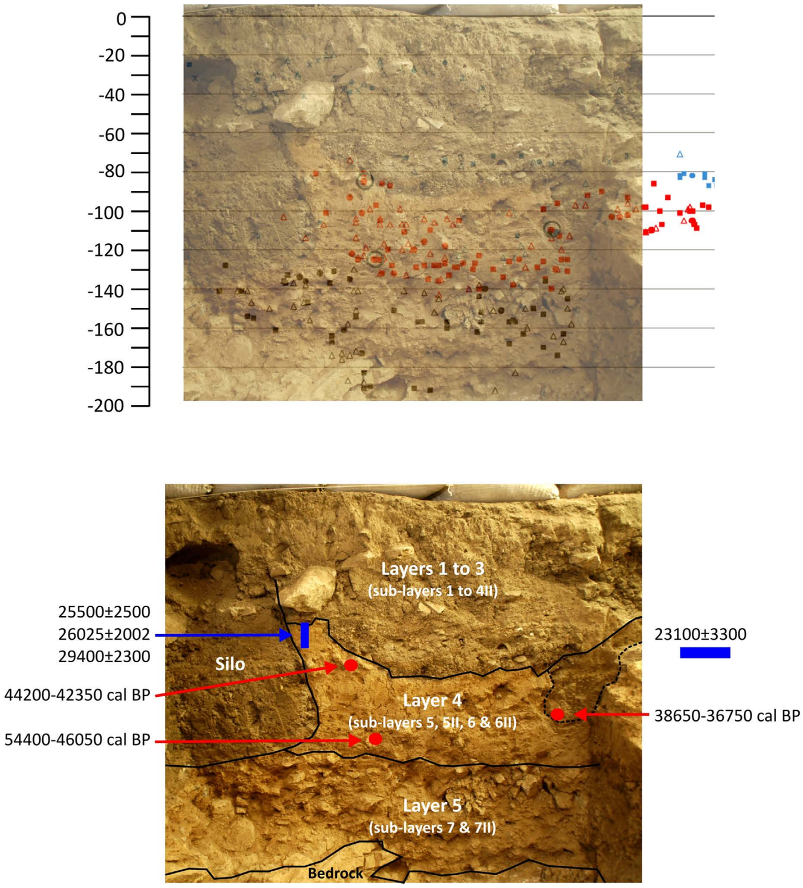

Figure 3. (Above) Stratigraphy (eastern section) along with transparent north-south longitudinal projection of the materials from squares in line E. (Below) Stratigraphy (eastern section) with location and results of the dated samples. Created by A. Ollé and B. Bazgir.

Additionally, *Capra* may have lived in the higher areas. The region surrounding the cave was likely relatively humid close to the river and drier farther away, i.e., more or less similar to the modern conditions.

The charcoal assemblage shows the presence of *Prunus* (Layers 4 and 5) and *Salix* (Layer 5). This would suggest the presence of tree cover composed of willows near the river and open woodland possibly composed of several species including plum trees farther away. The presence of these taxa support the interpretation of an open woodland under mild climatic conditions inferred from the other proxies.

The animal species present in Kaldar Cave originated long before the Late Pleistocene. Some of the species show changes during this period, but the material from Kaldar Cave is not yet sufficient to assess the evolutionary level of these species. Thus, from this perspective, the fauna has limited biochronological value at the scale needed here.

A preliminary taphonomic analysis of the small mammal assemblage has shown a high number of digested elements, suggesting predation activity. According to the different degrees of digestion observed in the remains (light, moderate and some heavy), a category 3 predator, such as the tawny owl (*Strix aluco*) or the Eurasian eagle owl (*Bubo bubo*[36]), might be responsible. Both species are compatible with the inferred habitat and are present in the area today[37]. Additionally, both have opportunistic hunting habits and are sedentary; therefore, their prey well represents the local ecosystem.

The large vertebrates in Layers 4 and 5 are represented by highly fractured bones and teeth. Only seven complete remains (8.2% in Layer 4 and 7.1% in Layer 5) were recovered (1 unciform of *Capra*, 1 coracoid of *Testudo*, 1 tarso-metatarso of Aves from Layer 4; 2 teeth, 1 sesamoid of *Capra* and 1 caudal vertebra of a small mammal from Layer 5). Remarkably, approximately half of both sets (44.7% and 50%, respectively) are shaft fragments. An analysis of the fracture edges (according to Villa and Mahieu[38]) shows that breakage of the bones occurred when they were fresh because most fracture delineations are curved or v-shaped (59.4%) and longitudinal (36.8%), with oblique angles (85.8%). Despite the high degree of fracturing of the large vertebrate bones and teeth in Layers 4 and 5, the assemblages on the whole appear to be well preserved. Post-depositional modifications were generally scarce in the Kaldar assemblage, except for black stains from manganese oxide deposits, which were found on 24.1% of the Layer 4 remains and on 30.9% of the Layer 5 remains, and the cemented sediment attached to surfaces, which were found on 18.2% of the Layer 5 remains. These modifications suggest alternating damp and dry

	Layer 4	Layer 5
Mammals		
Carnivora		
Mustelidae indet.		x
Perissodactyla		
Equus sp. (horse)	x	
Artiodactyla		
Sus scrofa (wild boar)	x	
Capreolus sp. (roe deer)		x
Cervus elaphus (red deer)	x	x
Capra cf. *aegagrus* (goat)	x	x
Rodents		
Microtus gr. *socialis* (social vole)	x	x
Chionomys cf. *nivalis* (European snow vole)	x	
Ellobius cf. *lutescens* (Transcaucasican mole vole)		x
Ellobius cf. *talpinus* (northern mole vole)	x	
Ellobius sp. (mole vole)	x	x
Cricetulus cf. *migratorius* (migratory hamster)	x	x
Mesocricetus cf. *brandti* (Turkish hamster)	x	x
Calomyscus sp. (mouse-like hamster)		x
Meriones spp. (two morphotypes of gerbil)	x	x
Cf. *Allactaga* sp. (toad jeroba)		x
Myominus sp. (mouse-tailed dormouse)		x
Dryomys cf. *nitedula* (forest dormouse)		x
Apodemus cf. *flavicollis* (yellow-necked mouse)	x	x
Mus cf. *musculus* (house mouse)	x	x
Birds		
Aves indet.	x	
Reptiles		
Agamidae indet. (agamid lizard)	x	x
Gekkonidae indet. (gecko)		x
Scincidae indet. (skink)		x
Lacertidae indet. (lacertid lizard)	x	x
Pseudopus sp. (glass lizard)		x
Eryx sp. (sand boa)	x	x
Colubrinae indet. (6 morphotypes)		x
Elapidae indet. (cobra)		x
Viperidae indet. (viper)	x	x
Testudo sp. (tortoise)	x	
Amphibians		
Bufo sp. (toad)		x
Anura indet.	x	
Crustaceans		
Crustacea indet. (crab)	x	

Table 3. Distribution of the faunal taxa identified in Kaldar Cave, Layers 4 and 5.

periods in the cave during the formation of Layer 5. Furthermore, sub-aerial weathering (stage 1 according to Behrensmeyer[39]) has been identified in just one specimen in each of the layers.

Evidence of anthropogenic activity appears in three ways: cut marks, bone fracturing, and cremations (Supplementary Fig. S4). Cut marks were observed on thirteen specimens: five from Layer 4 and eight from Layer 5. The remains from Layer 4 are long bones (humerus of Caprini, two tibia fragments and one femur of Cervidae and a long bone shaft of an indeterminate mammal). The cut marks appear in the form of slicing and scraping marks, and all instances are located on the shaft portions, indicating the defleshing of the carcasses. In Layer 5, the elements with cut marks comprise one radius and one tibia of *Capra*, one rib and one caudal vertebra of indeterminate taxa and four indeterminate long bone fragments. The incisions on the rib fragment were located on the neck of the bone and were associated with disarticulation activities. The incisions on the caudal vertebrae were located in the central part of the bone. The positions of the marks suggest that they are related to skinning tasks.

Other bones have cut marks in midshaft positions, indicating defleshing of the carcasses. The *Capra* radius with cut marks also had an impact point produced by the anthropogenic breakage of the bone.

Among the anthropogenic modifications of the bones in Kaldar Cave, the most important are the changes in coloration due to cremation, which is present in all layers. Fully 23.2% of the remains of the assemblage are burned (24.1% in Layer 4 and 21.8% in Layer 5). These remains include charred (black coloured, 34.4%) and rubefacted (brown and red coloured, 9.4%) bones. Bones with multiple colours are also common (53.2% of the burned bones). The most common combination is rubefacted (brown) and charred (black) colours (46.9%) on the same bone, although partially calcined (grey-blue-white colours) specimens are also present. The presence of multiple colours on the surface of the bones has been associated with meat cooking[40]. The distribution of the colours is homogeneous on the surface and affects the fracture edge and the cortical and medullar faces, suggesting that the bones were burned after they had been broken. According to several experimental studies[40–42], the presence of multiple colours indicates that the bones (regardless of the size) experienced cremation damage when they were fresh and unburied. The origin of this modification may be related to cooking but may also be related to their use as fuel for the maintenance of fires, cleaning of the living floor, or accidentally building a fire near the location where the bones had been deposited.

Little carnivore activity is recorded by the assemblage. Three bones in Layer 4 (1 tibia of Cervidae and 2 indeterminate long bones) showed carnivore tooth marks (Supplementary Fig. S4e). It is difficult to determine the size of the carnivore because only a few tooth marks are recorded. However, the low frequency of these modifications suggests carnivores played a limited role in the formation and/or modification of assemblage.

The zooarchaeological results suggest that not only were the early AMHs that occupied Kaldar Cave among the first to come into contact with large Palaearctic mammals but that they also quickly adapted to exploiting them as a resource.

Lithic industry. The technological analysis of the archaeological samples associated with the Mousterian assemblage from Kaldar Cave (Layer 5 - sub-layers 7 and 7II) indicates that by-products (fragments and flake fragments) are the most common elements (12%) followed by retouched tools (10.8%), Levallois flakes (8.5%), cortical pieces (5.8%), Levallois blades (4%), Levallois points (2.4%), Levallois cores (0.8), other types of cores (0.8%) and hammerstones (0.4%). A large amount of debris (54.5%) is also present in the assemblage. The flakes are dominated by Levallois and cortical pieces, mostly with elongated morphologies and predetermined pointed shapes. Among the 82 flakes counted, 24.4% are cortical pieces, 24.4% are retouched, 20.7% have pointed shapes, 15.8% are broken, and 15.8% show enough major characteristics to be defined as a Levallois flake. Among the blade group, 37.1% are pointed in shape, 25.9% do not fit within a standard category, 14.8% are cortical, 11.1% are broken, 7.4% are retouched, and just one core (3.7%) was found. The retouched artefacts are dominated by marginal and broken retouched flakes (37%), Mousterian points (26%), different types of scrapers (24.1%), retouched points (5.6%), retouched blades (3.7%), Tayac points (1.8%), and limace (1.8%). The points (including Mousterian, Levallois, retouched and Tayac), along with pointed flakes and blades, comprise 11.4% of the entire assemblage in this layer. Among the material other than debris, the points and pointed elements comprise 25.1% of the assemblage in this layer. Mousterian points, Levallois points and retouched points comprise 2.8%, 2.4% and 0.6% of the assemblage, respectively. Not counting the debris, the Mousterian points and Levallois points comprise 6.2% and 5.3% the assemblage, respectively (Table 4).

The low number of cores (all exhausted) among the Mousterian assemblage from Kaldar Cave could be meaningful. This observation is in agreement with the techno-typological results from the Mousterian assemblage of the nearby Kunji Cave[43]. Given the notable scarcity of cores, the absence of refittable pieces, the large differences between the size of the tools and the size of the cores and their negative scars, and the condition of the cores that are exhausted, the *chaîne opératoire* is incomplete. Therefore, many of the artefacts were likely carried in from elsewhere (Fig. 4 and Supplementary Figs SI, S5, S9A & B, S10A & B).

In the Upper Palaeolithic lithic assemblages of Layer 4 (sub-layers 5 & 5II), bladelets dominate (13%), followed by blades (12.5%), retouched tools (5.1%), cortical pieces (4.4%), by-products (3.5%), bladelet cores (1.6%), undetermined cores (1.4%; including a centripetal core), pointed flakes, blanks, and other types of tools (a borer and point; all less than 1%), a blade core (0.2%) and finally a considerable amount of debris (56.4%). Within the bladelet categories, there is a good representation of twisted bladelets (14.3%). Among the retouched tools, Arjeneh points are abundant, but pointed pieces (including Tanged, retouched points, pointed blades and bladelets and Arjeneh points) are more numerous (54.5%) compared to other types of retouched tools (Figs 5, 6 and 7, and Supplementary Figs S6, S7 and S8). Excluding the debris in this layer, the points and pointed elements comprise 11.2% of the entire assemblage. The next most abundant tools among the retouched pieces are the scrapers (including side-scraper, end scraper and nosed scraper), representing 18.2% of the tools. The number of flakes in this layer is very low (4.6% of the assemblage), and among the flakes, 3.7% are cortical flakes, 0.7% are pointed flakes and 0.2% are retouched flake (Table 5).

Despite the small size of the assemblage, a quick examination of the assemblage data from both Layer 5 (sub-layers 7 & 7II) and Layer 4 (sub-layers 5, 5II, 6 & 6II) shows a significant technological change from flake technology towards the production of blades and bladelets. However, to be more precise, a preliminary comparative analysis between the two layers was performed (Supplementary diagrams S1 to S5). In this analysis, we compared the weights and average values of metric measurements of various characteristics and attributes. The comparison of comparable categories was performed to provide meaningful results and to aid our interpretation of these two layers. Therefore, we compared Levallois cores vs. blade/bladelet cores, pointed blades vs. pointed blade/bladelets, and the retouched points, cortical pieces and cortical flakes (within the cortical pieces) from both the layers. Interestingly, our comparative analysis shows that significant differences are present among all the elements from the Middle and Upper Palaeolithic industries of Kaldar Cave. The weights and sizes of all

Layer 5 (sub-layers 7 and 7II)			N	%
Cortical piece	Cortical flake	20	29	**5.8**
	Cortical elongated point	1		
	Cortical blade	4		
	Pebble	1		
	Cortical scraper	3		
Levallois flake	Levallois flake	13	42	**8.5**
	Retouched flake	(20 counted in retouched tools)		
	Pointed flake	16		
	Broken flake	13		
Levallois blade	Pointed blade	10	20	**4**
	Cortical blade	(4 counted in cortical pieces)		
	Retouched blade	(2 counted in retouched tools)		
	Broken blade	3		
	Others	7		
Levallois point	—	12	12	**2.4**
Levallois core	—	4	4	**0.8**
Other types of core	Undetermined core	2	4	**0.8**
	Discoid core	1		
	Blade core	1		
Retouched tool	Mousterian point	14	54	**10.8**
	Marginal and broken retouched flake	20		
	Retouched point	3		
	Scraper	7		
	Nosed scraper	1		
	Side scraper	1		
	Retouched blade	2		
	Cortical scraper	4		
	Limace	1		
	Tayac point	1		
Byproduct	—	60	60	**12**
Debris	—	271	271	**54.5**
Hammerstone	—	2	2	**0.4**
Total	—	498	498	**100%**

Table 4. Quantified results of the lithics attributed to the Middle Palaeolithic Layer 5 of the 2014–2015 excavation season at Kaldar Cave.

the compared elements tend to be greater in Layer 5 than in Layer 4. The only exception was found within the retouched points. In this case, the average length and thickness are slightly greater for Layer 4 than for Layer 5.

Discussion

Considerable efforts have been made to address fundamental questions concerning the cultural remains associated with AMHs. These attempts have been based mainly on Upper Palaeolithic lithic assemblages and their potential places of origin.

Based on technological comparisons between the lithic assemblages found in Europe and those found in the Zagros, some authors report close typological similarities between the two and further propose the latter region as the most probable source of the technology, with an east-to-west diffusion into Europe. Consequently, the Upper Palaeolithic tradition of the Zagros has been termed the 'Zagros Aurignacian'[12–14,19–21,23–27,44]. Based on the techno-typological analysis of material from Warwasi, some also claim that the Baradostian (or Zagros Aurignacian) technology evolved from a local Mousterian foundation in the area.

In conflict with the statement by Tsanova[15] that the Iranian Zagros cannot be the source of bladelet technology and cultural modernity as the Warwasi rockshelter lacks both radiocarbon dates and evidence of antecedent blade technology, strong evidence indicates that the Zagros assemblages are not merely blade-based. Over 90 sites contain evidence of clear blade(let) production (defined as the Rostamian tradition), and these tools are all similar to and associated with those from the well-stratified Ghare-Boof locality[8–11].

Based on the detailed techno-typological analysis of the industries from Yafteh, some authors claim that the Baradostian technology of the Zagros is an Early Ahmarian-like technology[45,46] and conclude that, on the basis of the available data, continuity from the Zagros Mousterian to the Zagros Aurignacian cannot be confirmed. However, based on the gradual transition from the Middle Palaeolithic to the Upper Palaeolithic at Warwasi and the technological and chronological analogies between the lower Baradostian at Yafteh and the Early

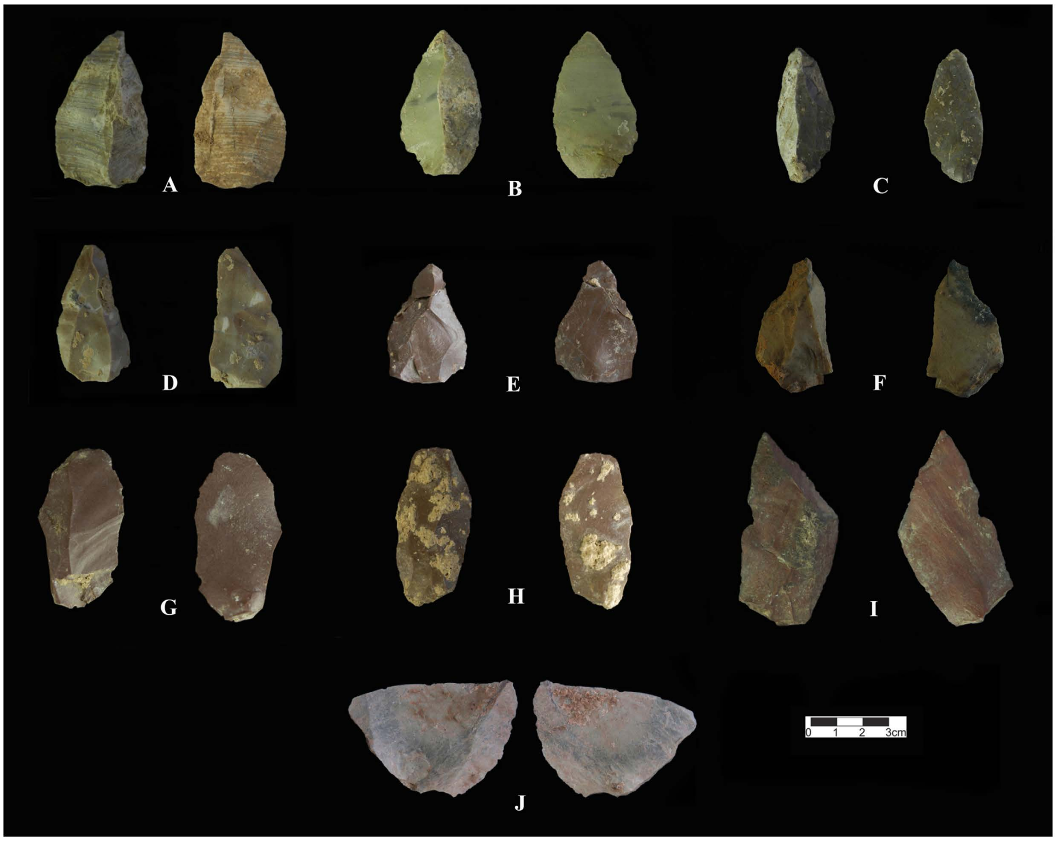

Figure 4. Selection of Middle Palaeolithic Levallois pieces from Kaldar Cave (Layer 5). (**A**) and (**B**); Point, (**C**); Elongated cortical point/Pointed flake with cortical butt, (**D**) to (**F**); Levallois point, (**G**) and (**H**); Elongated Levallois flake, (**I**); Levallois elongated pointed flake, (**J**); Levallois flake. Created by B. Bazgir.

Ahmarian, the Zagros region remains a potential candidate for the origin of the Aurignacian[5,32]. In a very recent typo-technological study on the Ghar-e-Khar lithic assemblages[33], the authors estimated the potential of the area for future research. Nevertheless, in addition to the small sizes of the studied assemblages, methodological problems (e.g., using 10- to 30-cm arbitrary levels) during the excavation and the lack of absolute chronometric data might raise concerns similar to those for the material from Warwasi and cast doubt on the results from Ghar-e-Khar, which are not compelling. Thus, the hypothesis of Middle-to-Upper Palaeolithic continuity in Zagros and the possibility of a gradual transition are hard to assess due to the current state of the technological data[33].

Similar to Yafteh, the Üçağizli sequence in Turkey provides some evidence of evolution from the Initial Upper Palaeolithic (IUP) into the early Upper Palaeolithic "Early Ahmarian". Given the absence of Middle Palaeolithic underlying the IUP layers in Üçağizli, however, the site offers little to the discussion of the appearance of the IUP in the region[47] (see also Shidrang[32]). Additionally, an IUP assemblage has also been discovered in Manot Cave, to the north of Mount Carmel[48]. The presence of both Mousterian and Baradostian cultural remains in Kaldar Cave and the recent chronometric data can be used to address many of the stated uncertainties associated with the transition process.

In regard to the terms "IUP", "Aurignacian", "Baradostian" and "Zagros Aurignacian", our data from Kaldar Cave and other excavated localities[35] support the arguments advanced by Kuhn and Zwyns[49] with respect to the technological diversity within the assemblages and the long duration of the Upper Palaeolithic in Kaldar. We therefore avoid using the term "IUP" for this assemblage. On the other hand, we cannot simply assign the term "Aurignacian" to the assemblage based on certain similarities with assemblages from European sites. However, our observations and technological analysis of the Kaldar assemblage are in agreement with that of Olszewski[12–14,19–24,44]: certain similarities do exist, yet the Zagros industry differs from the purely European Aurignacian. Therefore, to us, the terms "Baradostian" or "Zagros Aurignacian" are more appropriate.

Notably, based on our earlier technological work[35], the recent TL dates are older than we anticipated for the lithic assemblages of the uppermost part of Layer 4. These dates have led us to abandon the Epipalaeolithic designation we previously applied to these bladelet assemblages.

The AMHs in Kaldar Cave may have been among the first of their kind to interact with Palaearctic fauna. Thus, many of the species were new to them. In this part of Eurasia, the Palaearctic had an east-west-oriented southern border with the newly defined Saharan-Arabian biogeographic realm. The Zagros Mountains acted as an extension of the Palaearctic into the more southern realm[50]. However, it is not known whether the boundary between these realms occupied the same location during the Late Pleistocene. The presence of large mammals is

Figure 5. Selection of Upper Palaeolithic retouched pieces from Kaldar Cave (Layer 4). (**A**); Cortical retouched double scraper, (**B**); Tanged point, (**C**) to (**F**); Arjeneh points, (**G**); Retouched blade, (**H**); Elongated retouched blade, (**I**); Point on blade with retouches on its distal portion of ventral face, (**J**); Retouched end scraper, (**K**); Retouched nosed scraper, (**L**); Mesial portion of a retouched bladelet point. Created by B. Bazgir.

indicative of the seasonality of the Palaearctic, but most of the reptiles have Saharan-Arabian affinities, and the rodents yield a mixed signal.

The fauna present in the mid-latitude Palearctic represent "interglacial" fauna, and similar faunas (albeit generally richer in species) occupied the area during previous interglacials. During glacial periods, these species survived in southern refugia, while cold-adapted species occupied the mid-latitudes. Iran may have acted as one of these refugia. Up to now, no typically glacial species has been recorded in Iran or other areas at similar latitudes. The Palaearctic mammal species recorded in Iran, and in particular in Kaldar Cave, are "interglacial", suggesting the presence of at least temperate conditions. In contrast, the herpetofauna clearly indicates warm conditions. This combination is consistent with a position at the limit of the two biogeographic realms during climatic conditions similar to those of today. Furthermore, the study period is thought to correspond to MIS3, which had conditions similar to the modern climate. Because there is no indication of faunal change between layers 4 and 5, the available evidence suggests that the cultural change was not related to climatic or environmental changes.

Methods

Radiocarbon dating. Radiocarbon dating of the five charcoal samples (listed in Table 4) was performed at the Oxford Radiocarbon Accelerator Unit (ORAU). The samples were chemically cleaned using the acid-base-wet oxidation-stepped combustion (ABOx-SC) protocol (after Brock and Higham[51], also see ref. 52) or a modification of the same. The ABOx-SC method was employed as it has been shown to remove contaminants from Palaeolithic-aged charcoal more efficiently than the routine acid-base-acid (ABA) protocol, often yielding significantly older dates (e.g. refs 51, 53–59). The analytical data obtained are shown in Table 4, and no data fall outside the expected ranges for well-preserved charcoal. The calibration of all the resulting AMS radiocarbon determinations was performed using the OxCal 4.2 software[60,61] and the IntCal13 calibration curve[62].

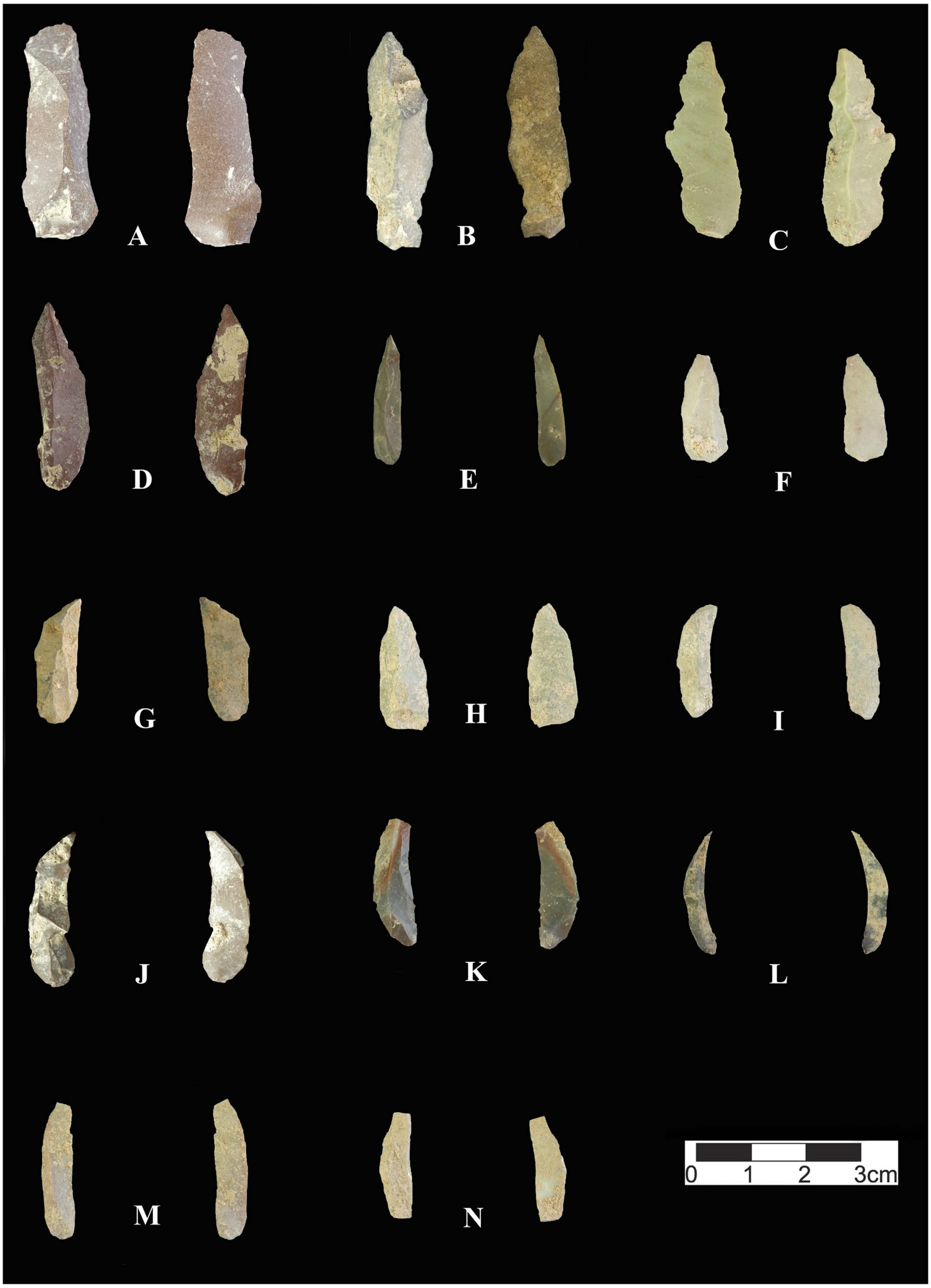

Figure 6. Selection of Upper Palaeolithic blades and bladelets from Kaldar Cave (Layer 4). (**A**) Elongated blade, (**B**) to (**D**); elongated pointed blades, (**E**) to (**H**); Pointed bladelets, (**I**) and (**N**); Dufour bladelets, (**J**) to (**M**); Twisted bladelets. Created by B. Bazgir.

Among the seven charcoal samples submitted, five yielded enough material for AMS radiocarbon dating after chemical preparation (see Table 6). Only three of these, however, yielded reliable radiocarbon dates following a congruent age-depth pattern; the two others were substantially younger. This is almost certainly due to taphonomic influences. While it would be useful to incorporate the Palaeolithic-aged results into a Bayesian model, we cannot as we have too few results at this time. More dating work is currently underway, and we hope to be able to report new results in the future. In Fig. 8, we show the calibrated results for the Palaeolithic specimens (see Table 2 for the data).

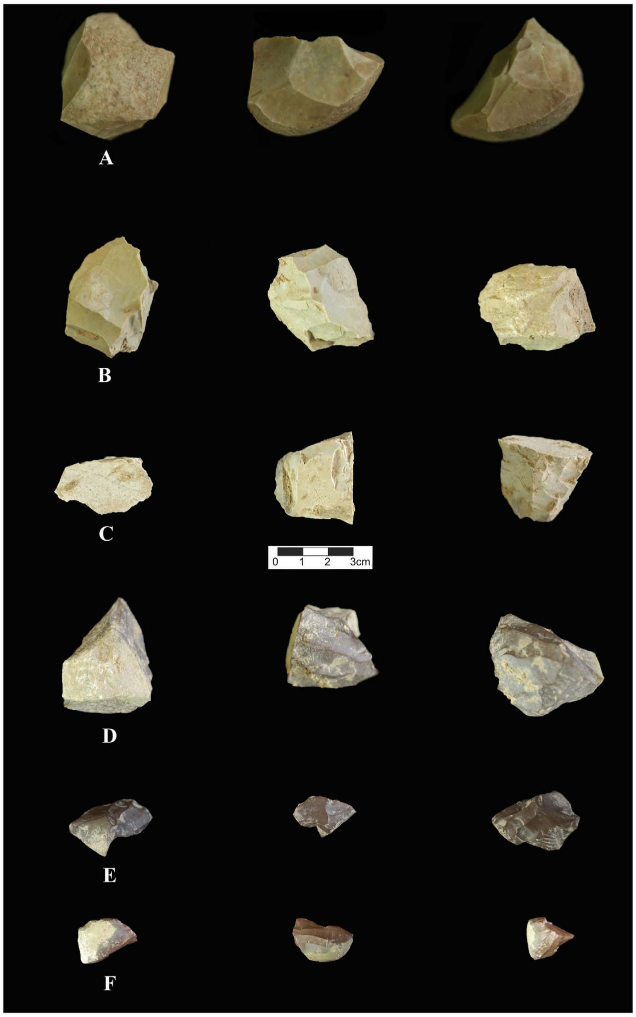

Figure 7. Selection of Upper Palaeolithic cores from Kaldar Cave (Layer 4). (**A**): Flake core, (**B**,**C** and **F**); Bladelet core, (**D**); Broken carinated core (**E**); Carinated core/carinated scraper. Created by B. Bazgir.

TL dating. Thermoluminescence dating was performed on five heated samples (four heated sediments from two fire places in the upper most part of Layer 4 and one burnt flint from Layer 5) at the Research Centre for Conservation & Restoration of Cultural Relics of the Research Institute of Iranian Cultural Heritage (RICHT). At present, the samples from Layer 4 have successfully been dated. Three of the dated samples come from a fireplace within squares E6/7 and one from square E5 (Table 1).

For the sample preparation and instrumentation, the outer surface (3 mm) of the samples was removed. To account for the alpha radiation contribution to the natural dose measurements, the fine grain technique is used (ibid). Alpha radiation travels an extremely short distance in heated objects (approximately 25 μm[63]). Thus, we used grains less than 10 μm in size. The samples were crushed and treated with 10% HCl to remove carbonates and organic material. Then, all samples were washed with distilled water and then with acetone. Finally, the grains were suspended in acetone and deposited on aluminium discs that were 10 mm in diameter and 0.5 mm in thickness.

The TL measurements were performed using an ELSEC7188 instrument. The potassium contents of the samples were determined by flame photometry. To determine the contributions from U and Th, the "pairs" technique was used; thus, the dose rate was measured using a 7286 low-level alpha counter[64]. External dose rates were measured by in situ dosimetry[65]. The CaF2 TL-Dosimeter was located in site for 36 days. These values were calculated for different levels, up-level: 0.787 mGy/a, down-level: 0.660 mGy/a. Measurements of the water content and fading test for all samples were considered (Table 1).

Conclusions

The newly excavated sequence in Kaldar Cave provides evidence for the replacement of the Mousterian industry, usually associated with Neanderthals, by the Baradostian industry, similar to the Aurignacian, which is unique to anatomically modern humans. Radiocarbon dates suggest that this may have occurred prior to 49,200 ± 1800 BP, probably during the relatively warm MIS3. The faunal evidence is consistent with the replacement occurring

Layer 4 (sub-layers 5, 5II, 6 and 6II)			N	%
Cortical piece	Cortical flake	16	19	**4.4**
	Cortical blade	1		
	Nodule	2		
Blade	Pointed blade	6	54	**12.5**
	Blade with truncated faceted butt	1		
	Blade	47 (2 counted in retouched tool)		
Bladelet	Twisted bladelet	8	56	**13**
	Bladelet point	2		
	Bladelet	46 (5 counted in retouched tools)		
Blade core		1	1	**0.2**
Bladelet core		7	7	**1.6**
Other types of core		6 (1 is a centripetal core)	6	**1.4**
Retouched tool	Nosed scraper	1	22	**5.1**
	End scraper on blade	1		
	Blade scraper	1		
	Side scraper	1		
	Arjeneh point	4		
	Tanged point	1		
	Retouched pointed bladelet	3		
	Retouched bladelet	2		
	Retouched pointed blade	2		
	Retouched point	2		
	Unfinished retouched point	1		
	Retouched flake	1		
	Retouched blade	1		
	Retouched piece on a broken blade	1		
Other types of tool	Borer	1	1	**0.3**
Pointed flake		4	4	**0.9**
Blank/fragment		3	3	**0.7**
Byproduct		15	15	**3.5**
Debris		243	243	**56.4**
Total			431	**100%**

Table 5. Quantified results of the lithics attributed to the Upper Palaeolithic Layer 4 of the 2014–2015 excavation season at Kaldar Cave.

during MIS3 and does not support a coincident climatic change. Kaldar Cave is situated in the southernmost part of the Palaearctic biogeographic realm. Evidence from Kaldar Cave is among the oldest to show that AMHs were capable of exploiting the Palaearctic fauna and were thus well adapted to this new environment, which they colonized shortly after the period of time recorded in the cave.

Excavations at Kaldar Cave have yielded evidence for Baradostian (Layer 4) and Mousterian assemblages (Layer 5) in stratigraphic superposition. This is an exceptional find in the Zagros. The preliminary technological analysis on the lithic industry from both layers indicates a clear shift from flake production to blade and bladelet technology. Furthermore, despite the small size of the lithic assemblage so far, the quantitative comparative analysis shows a significant difference between elements within the Middle and Upper Palaeolithic layers. The homogeneity of the differences between all the compared elements—that is to say, the greater weight and size of the items in the Mousterian assemblage compared to those of the Upper Palaeolithic assemblage—could be a reliable foundation for interpretation and understanding the two industries.

We have obtained new chronometric data from the site. Four TL dates from the uppermost Layer 4 revealed ages that ranged from 23100 ± 3300 to 29400 ± 2300 BP.

The three ^{14}C dates from Layer 4 and sub-layers 5 and 5II produced results in the ranges of 38650–36750 cal BP, 44200–42350 cal BP, and 54400–46050 cal BP, respectively (all at 95.4% probability). The wide chronometric ranges and few dates do not allow us to make a confident and precise assessment of the age of the transition to the Upper Palaeolithic. Further work is needed to refine the chronology.

In addition to the presence of a clear Mousterian industry in the >0.5-m-thick Layer 5 and despite the need for more chronometric data, the obtained dates from the lower part of the Upper Palaeolithic sequence in Kaldar

OxA	Species	Used (mg)	Yield (mg)	%Yld	%C	$\delta^{13}C$ (‰)
X-2645-11	*Prunus* cf. *amygdalus*	59.91	8.71	14.5	81	−23.4
X-2645-12	*Prunus* cf. *amygdalus*	93.41	6.23	6.7	82.2	−24.5
32238	*Prunus* cf. *amygdalus*	107.6	10.81	10	69.7	−23.0
32239	*Quercus* sp. deciduous	105.16	16.65	15.8	71.7	−23.1
32240	*Quercus* sp. deciduous	9.83	6.5	66.1	75.1	−27.1

Table 6. Analytical and sample data for the charcoal dated from Kaldar Cave. OxA-X determinations involved a modified ABOx-SC preparation. The other determinations involved the ABOx-SC method. All data are acceptable and within expected parameters. **Denotes an AMS result in fraction Modern. This determination post-dates AD 1950.

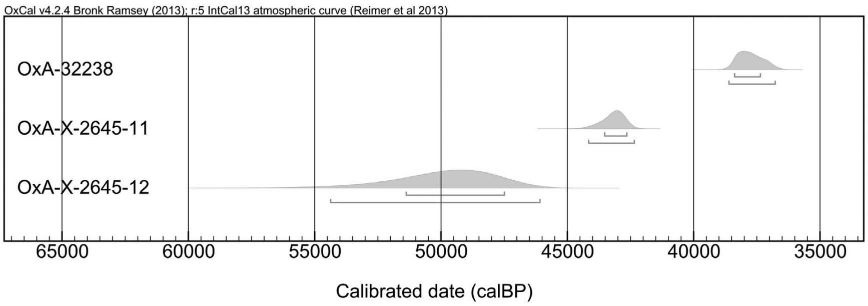

Figure 8. Calibrated results of the Palaeolithic specimens. Created and modified in the Research Laboratory for Archaeology and the History of Art, University of Oxford, by T. Higham, K. Douka and L. Becerra-Valdivia.

Cave are some of the earlier dates attributed to a lithic industry produced by AMHs in western Asia. Although we do not intend to challenge the Levantine dispersal theory, previous work has noted that the Aurignacian may not have originated in only one area[22] (see also Groucutt[66]). It has been suggested that the ages of the so-called "transitional" or Initial Upper Palaeolithic layers at Ksar Akil may represent that the transition from the Middle to Upper Palaeolithic in this area (and possibly in the wider northern Levant) occurred later than previously estimated. This finding would cast doubt on the assumed singular role of the region as an origin for human dispersal into Europe[67].

Another important clue derived from the preliminary quantified results of the Mousterian and Upper Palaeolithic lithic industries in Kaldar Cave is the high percentage of points and pointed elements in both the layers. This abundance may indicate that the site functioned as an important hunting camp in the Zagros Mountains during both the Middle and Upper Palaeolithic times. This hypothesis appears to be supported by the zooarchaeological evidence. Hence, Kaldar Cave provides one of the oldest examples of modern human existence in this part of the world and provides data on how these populations coped with the Palearctic climatic and environmental situations, which were new to them.

To reach a consensus regarding the Middle to Upper Palaeolithic transition/continuity, several lines of evidence are required. Indeed, accurate information and maximum control of the context, including careful sampling for chronometric dating from well-stratified sites and detailed techno-typological analysis, are crucial factors. Our understanding of the behavioural dimension of the transitional phenomenon would also benefit from more excavations using multidisciplinary methods, including spatial analysis and functional aspects.

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Author Contributions

B. Bazgir, A. Ollé, and L. Tumung investigated the site in detail, studied the lithic industry, and monitored the data recovered from the stratigraphy. L. Becerra-Valdivia, K. Douka and T. Higham performed the ^{14}C dating and helped revise the draft. J. van der Made and D. Arceredillo studied the macrofauna. A. Picin collaborated on the early phases of writing the draft and contributed to some excavation days. P. Saladié performed the zooarchaeological studies. J.M. López-García, M. Fernández-García and I. Rey-Rodríguez studied the small mammals. H.A. Blain studied the amphibians and reptiles. E. Allué studied the charcoal assemblage. F. Bahrololoumi and M. Azimi performed the TL dating. M. Otte and E. Carbonell provided the research strategy and acted as the senior archaeological advisors. B. Bazgir wrote the paper and all the co-authors contributed to the final version of the manuscript.

Additional Information

Supplementary information accompanies this paper at http://www.nature.com/srep

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SUPPLEMENTARY INFORMATION

Understanding the emergence of modern humans and the disappearance of Neanderthals: Insights from Kaldar Cave (Khorramabad Valley, Western Iran)

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Description of the new material of large mammals from Kaldar Cave

Remains of large mammals have been described from a previous excavation at Kaldar Cave[1]. Recent excavations yielded new material, including new species. The updated faunal list is given in Table 3. The most relevant new fossils are described below.

An incisor (Fig. S11/2) from Layer 4 (sub-layer 5 II) belongs to *Equus*. Its size suggests a large horse, such as the caballoid horses, and not a small one such as *E. hydruntinus* or *H. hemionus*. Caballoid horses are seen as a single species[2], two[3] or even more species[4]. We assign the material to *Equus* sp.

A right upper canine of a cervid comes from Layer 5 (Fig. S11/1). The genera *Axis* and *Rucervus* do not have upper canines, the genus *Dama* only rarely has them[5], but in *Cervus elaphus*, both males and females have upper canines. By the criteria of D'Errico & Vanhaeren[6] and Arceredillo[7], the specimen from Kaldar belonged to a female, but it is not possible to infer the age of death. In Europe, the size of *Cervus elaphus* changed in time and the same changes seem to have occurred even South of the Caucasus[8,9,10]. However, the red deer material from Kaldar Cave does not allow to establish whether it belonged to a large or small sized population.

Caprini indet. cf. *Capra aegagrus* was previously identified on the basis of dental material. A lower third molar from Layer 5 (sub-layer 7) (Fig. S11/3) is peculiar in having an additional distal lobe. Normally there is a third lobe, consisting of a single cusp, but here there is a relatively wide third lobe, consisting of a single cusp, and a similar but narrower fourth lobe. The fourth lobe is worn by occlusion with the upper M^3. *Hemitragus* and *Capra* differ in that the latter has upper third molars with a distal extension at the buccal side, which is like a very narrow third lobe. *Hemitragus* and nearly all other bovids lack such an incipient third lobe. A short M^3, without such an extension, would never cause wear on the tip of a fourth lobe of an M_3. This tooth confirms thus the presence of *Capra* in Kaldar Cave.

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Supplementary figures

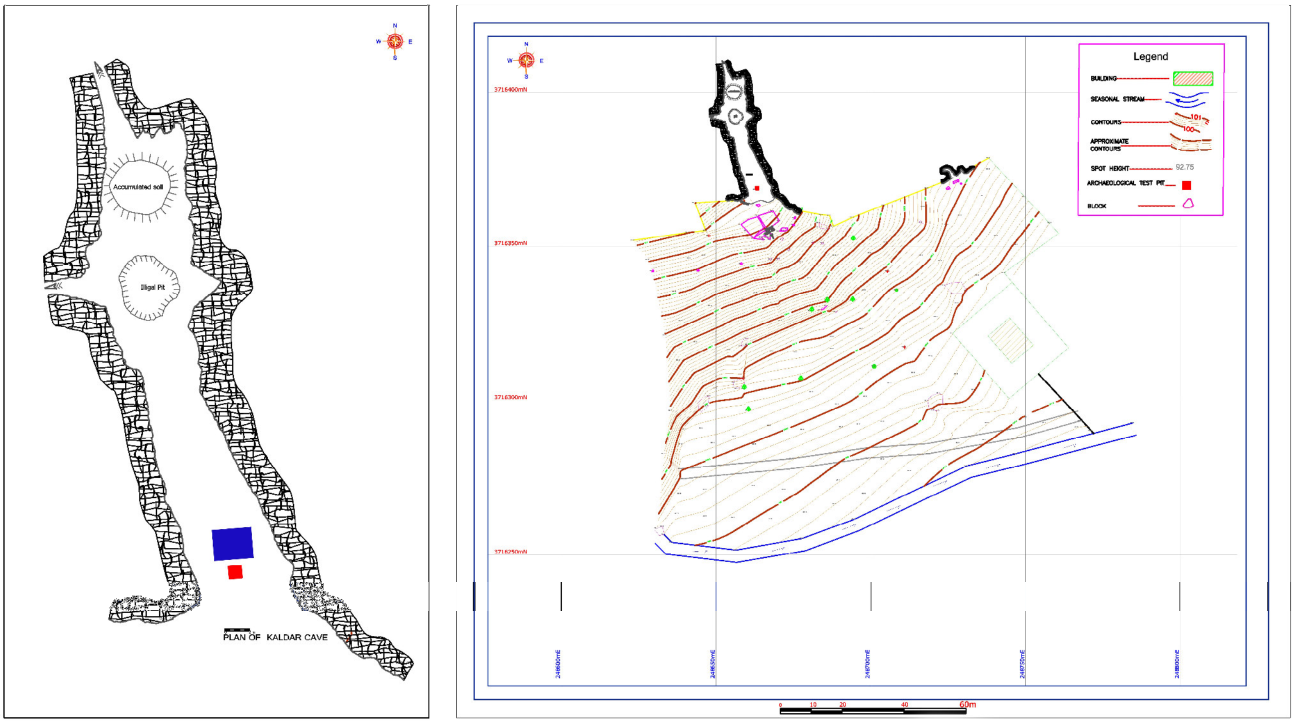


Figure S1. Detailed topographical map of Kaldar and its sounding area. The location of the new trench is shown in blue colour. Created by B. Bazgir, using AutoCad, Photoshop and Corel Draw softwares.

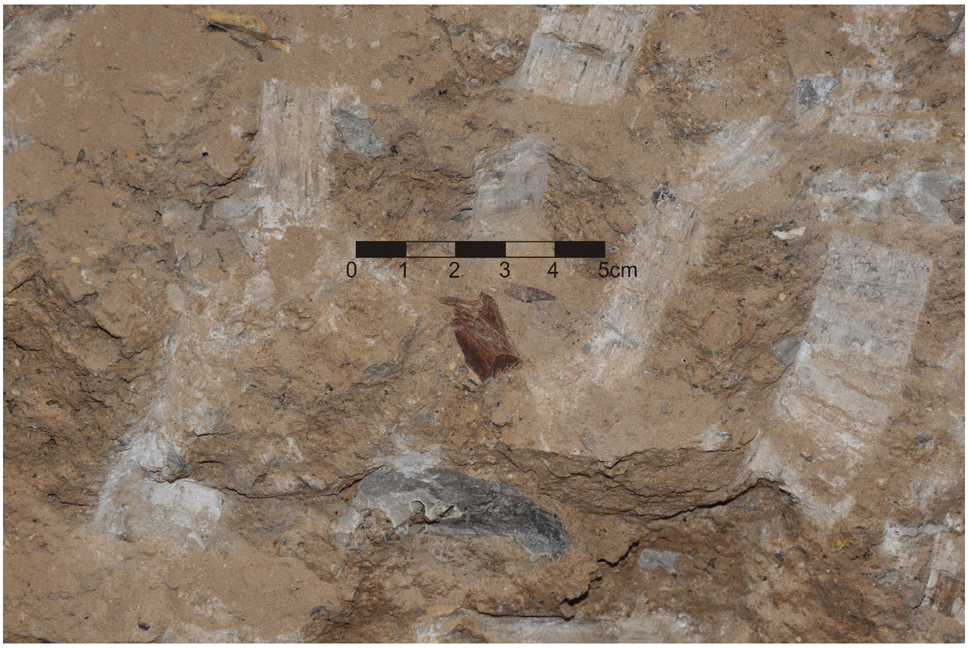


Figure S2. The high density of the deposit can be clearly seen with the traces of chisel marks. Photo by A.Ollé, modified by B.Bazgir.

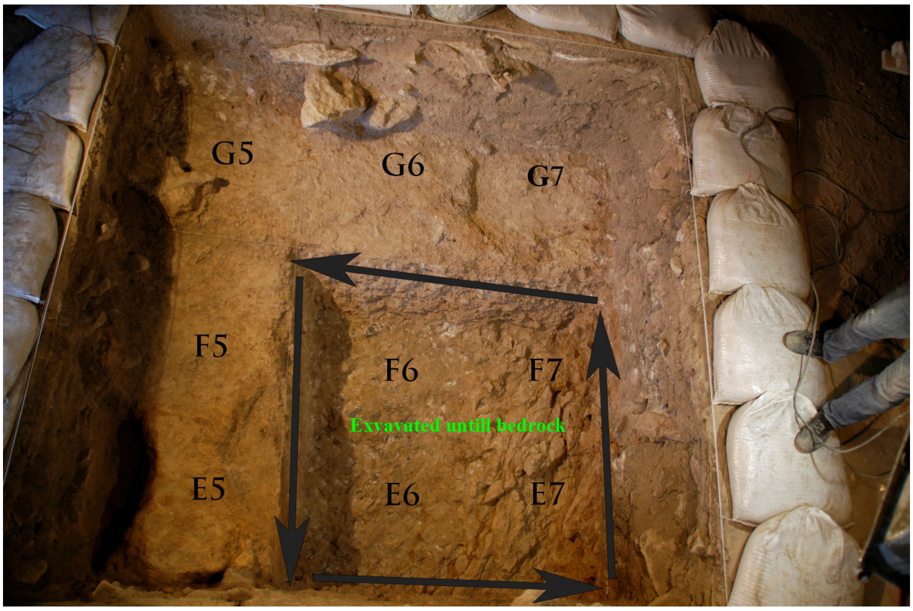


Figure S3. General view of the excavated trench. The squares between the arrows reached to the bedrock. Photo by B. Bazgir.

Figure S4. Examples of taphonomic modifications on Kaldar cave fauna specimens. a) Tibia shaft fragment of Cervidae with two groups of slicing marks (Layer 4); b) Percussion impact on the shaft of a Caprini humerus (Layer 4); c) Dorsal and ventral view of burned epiplastron of *Testudo* sp. (Layer 4); d) Slicing marks on a fragment of the shaft of a tibia of Caprini with two groups of slicing marks (Layer 5); e) Fragment of a long bone with carnivore score marks (Layer 4). Created by P. Saladié.

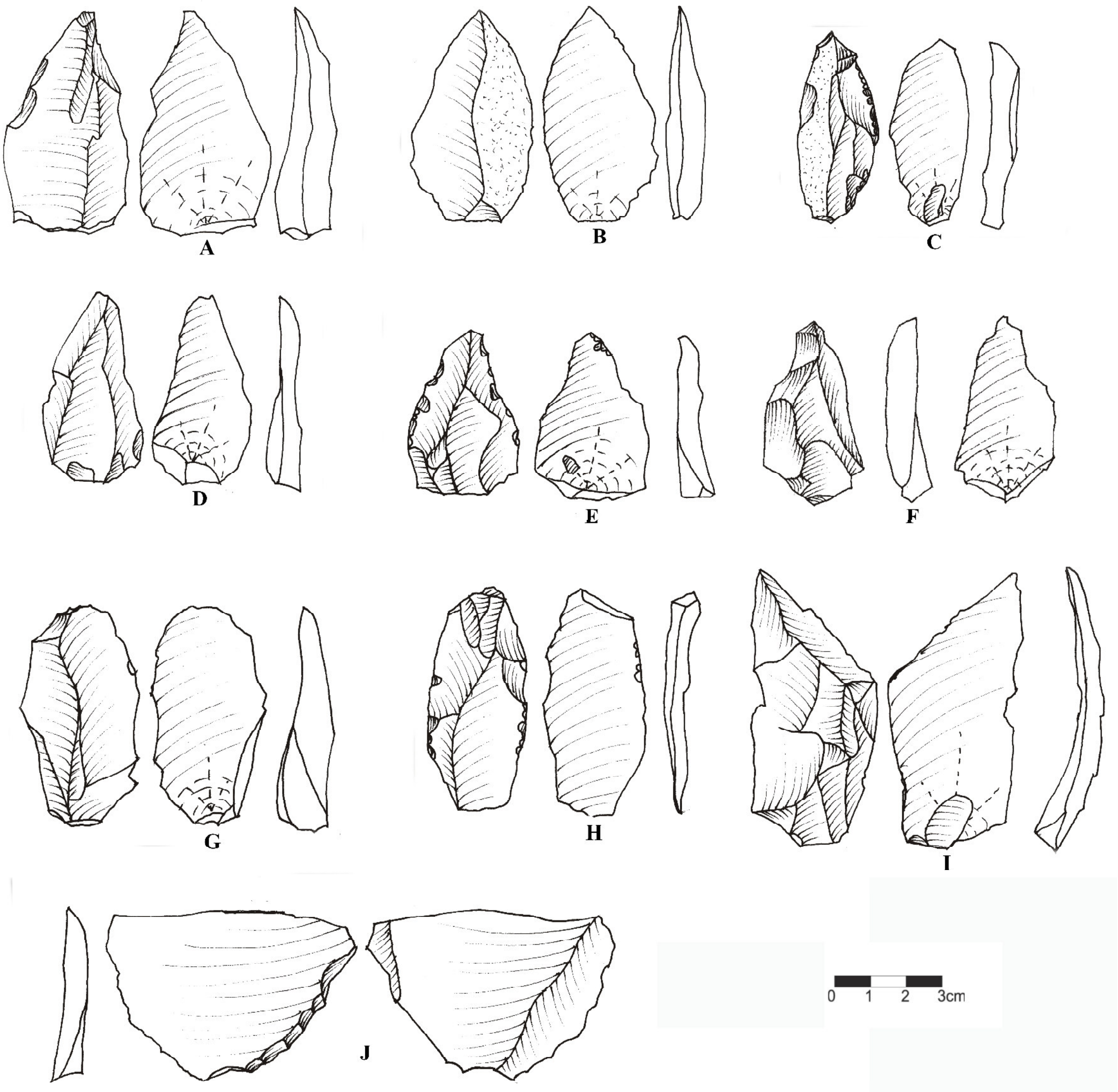


Figure S5. Selection of Levallois pieces from the Middle Paleolithic from Kaldar Cave (Layer 5). A&B; Point, C; Elongated cortical point/pointed flake with cortical butt, D to F; Levallois point, G&H; Elongated Levallois flake, I; Levallois elongated pointed flake, J; Levallois flake. Drawings by L. Tumung.

Figure S6. Selection of retouched pieces from the Upper Paleolithic of Kaldar Cave (Layer 4). A; Cortical retouched double scraper, B; Tanged point, C to F; Arjeneh points, G; Retouched blade, H; Elongated retouched blade, I; Point on blade with retouches on the distal portion of the ventral face, J; Retouched end scraper, K; Retouched bladelet point, L; Mesial portion of a retouched bladelet point. Drawings by L. Tumung.

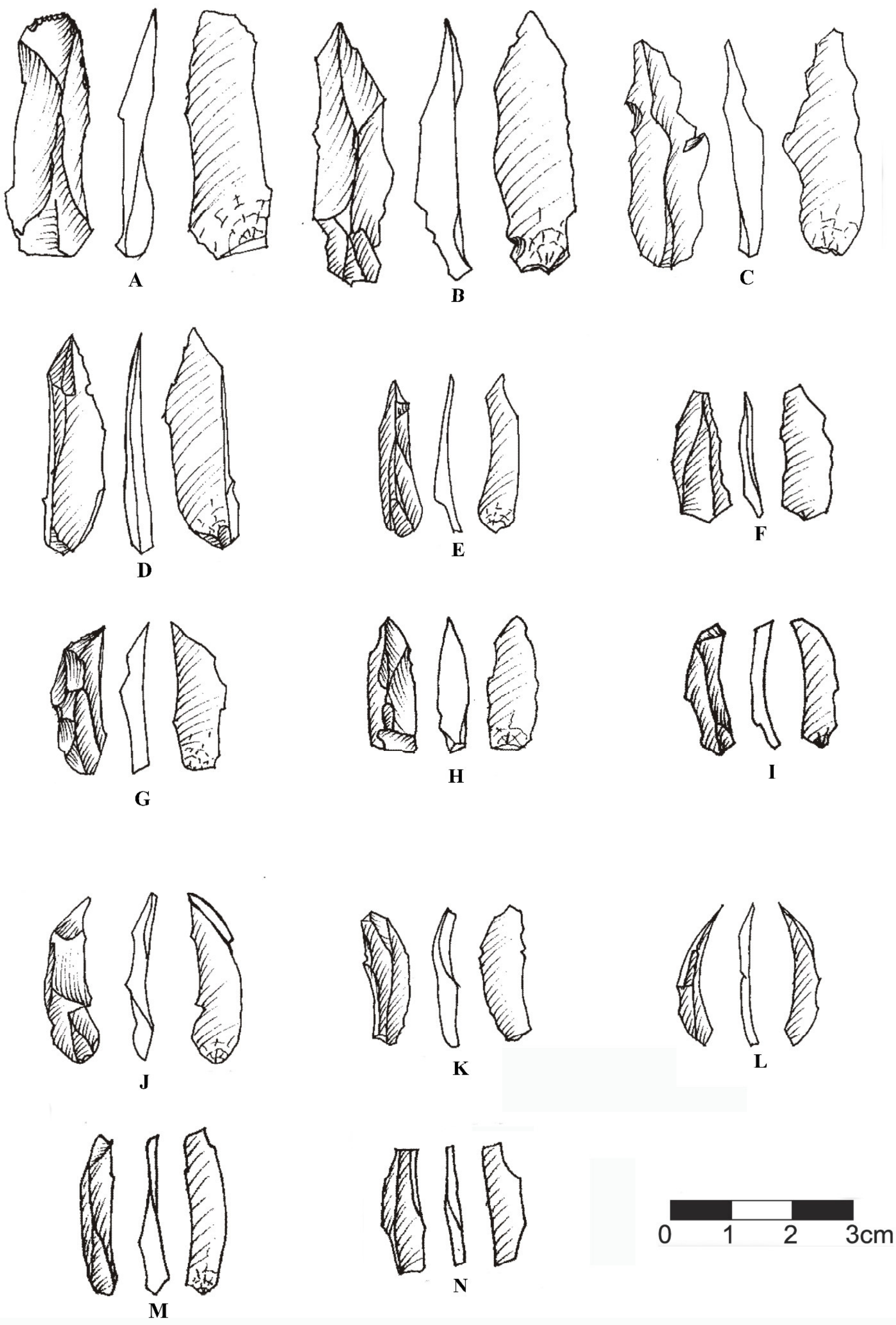


Figure S7. Selection of blades and bladelets of Upper Paleolithic from Kaldar Cave (Layer 4). A; Elongated blade, B to D; elongated pointed blades, E to H; Pointed bladelets, I &N; Dufour bladelets, J to M; Twisted bladelets. Drawings by L. Tumung.

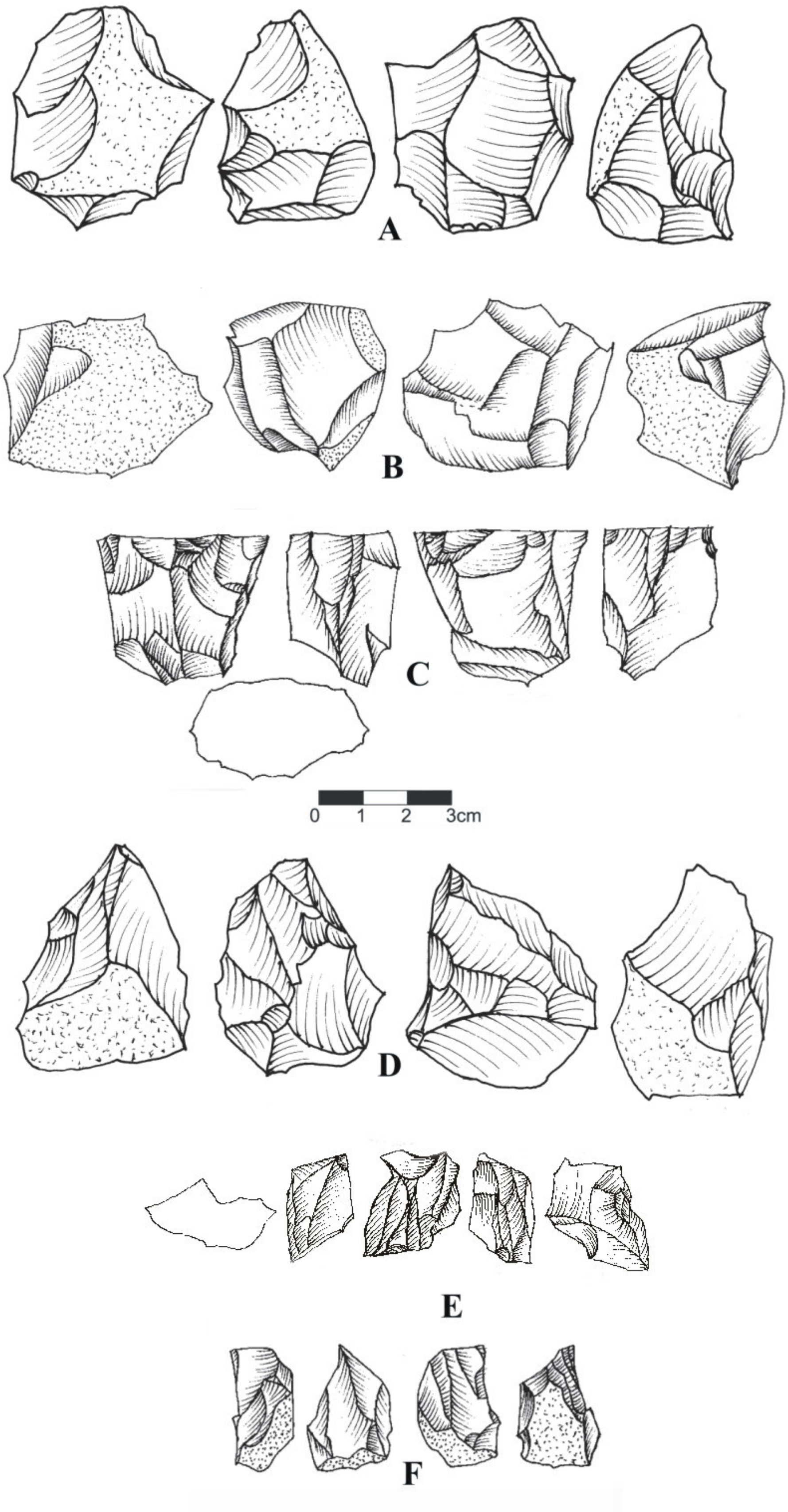


Figure S8. Selection of cores of Upper Paleolithic from Kaldar Cave (Layer 4). A: Blade core, B,C & F; Bladelet core, D; Broken carinated core E; Carinated core/carinated scraper. Drawings by L. Tumung.

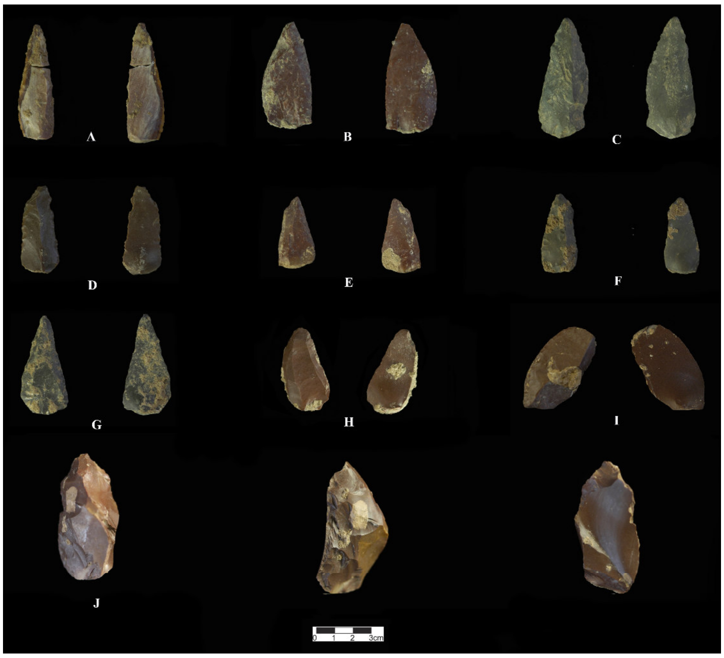


Figure S9A: Selection of retouched pieces from the Middle Paleolithic of Kaldar Cave (Layer 5). A to G; Mousterian points, H&I; Retouched side scrapers, J; Limace. Created by B.Bazgir.

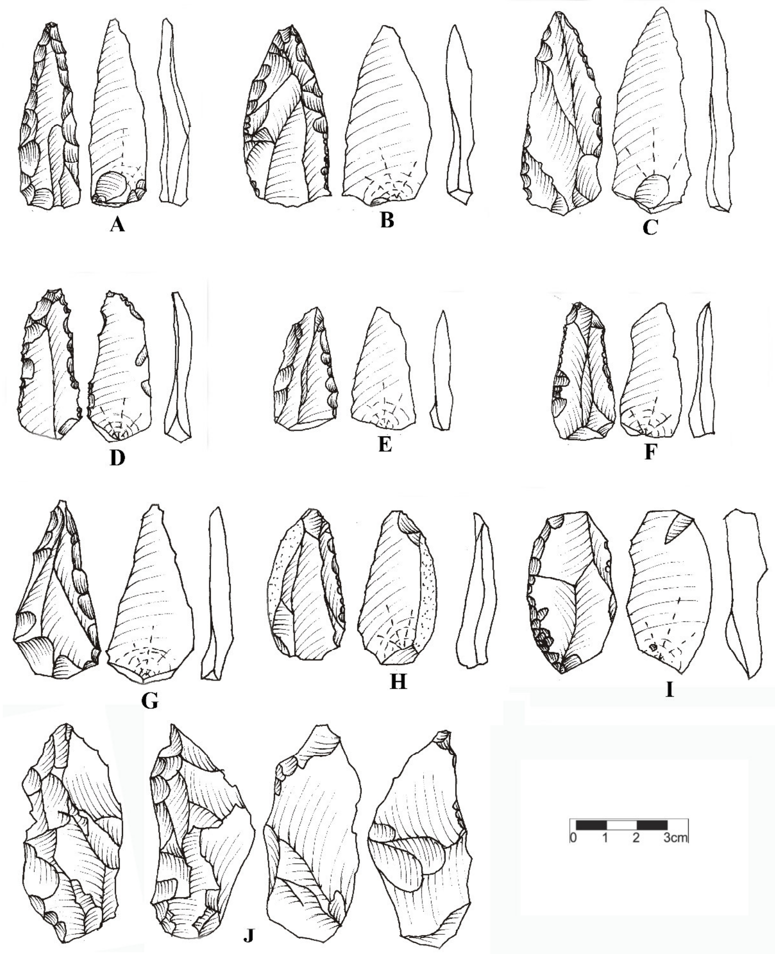


Figure S9B. Selection of retouched pieces of Middle Paleolithic from Kaldar Cave (Layer 5). A to G; Mousterian points, H&I; Retouched side scrapers, J; Limace. Ddrawings by L. Tumung.

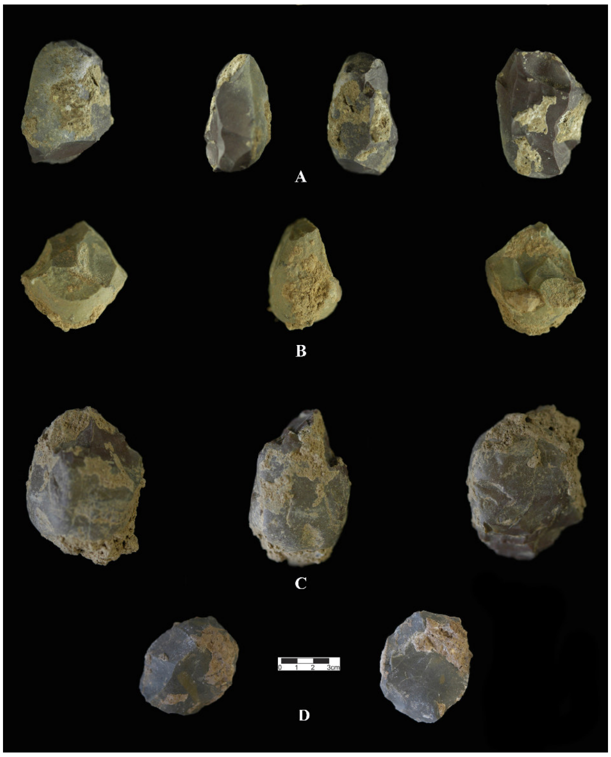


Figure S10A. Selection of cores of Middle Paleolithic from Kaldar Cave (Layer 5). A; Cortical Levallois unidirectional core, B; Cortical unidirectional core C; Predetermining centripetal core, D; Levallois centripetal core. Created by B.Bazgir.

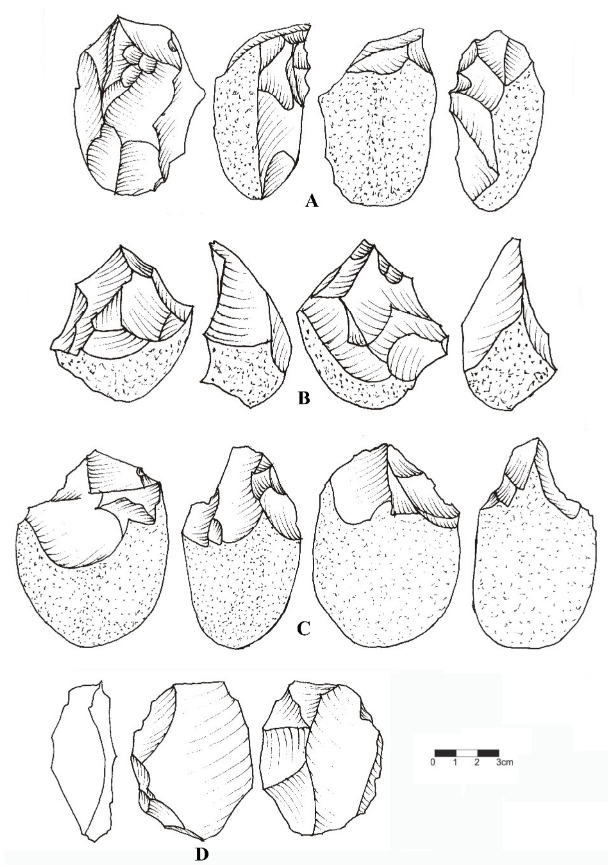


Figure S10B. Selection of cores of Middle Paleolithic from Kaldar Cave (Layer 5). A; Cortical Levallois unidirectional core, B; Cortical unidirectional core C; Predetermining centripetal core, D; Levallois centripetal core. Drawings by L. Tumung.

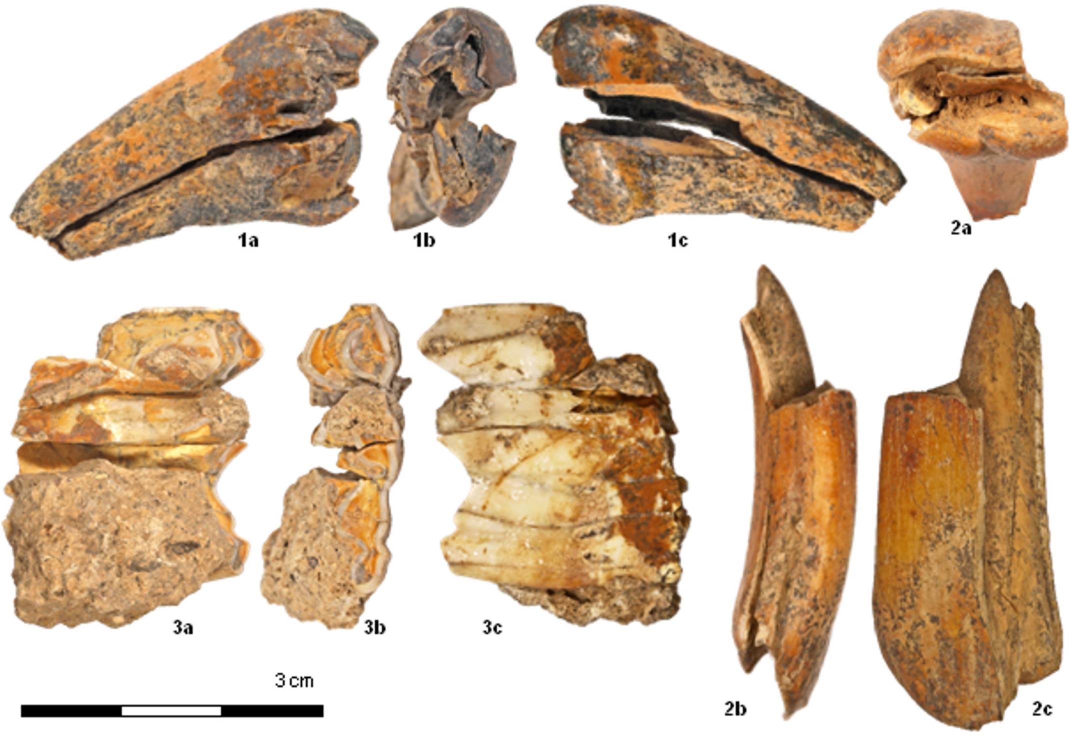
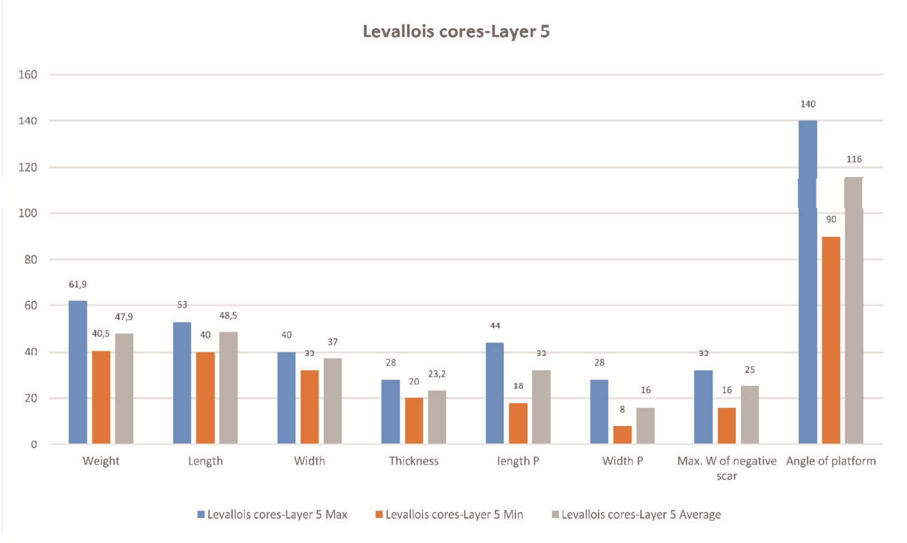


Figure S11. Fossils from Kaldar Cave: 1) KLD-2014- E5-1430 - right upper canine of a female of *Cervus elaphus* from Layer 5: a) lingual, b) occlusal, and c) buccal views; 2) KLD-2014-E6-879 - left upper incisor of *Equus* sp. from Layer 4 (sub-layer 5 II): a) occlusal, b) mesial, and c) labial views; 3) KLD-2014-F6-814 - left lower third molar of *Capra* sp. from Layer 5 (sub-layer 7); Figure 1/2 not to scale. Created and modified by J.van der Made.

Supplementary diagrams



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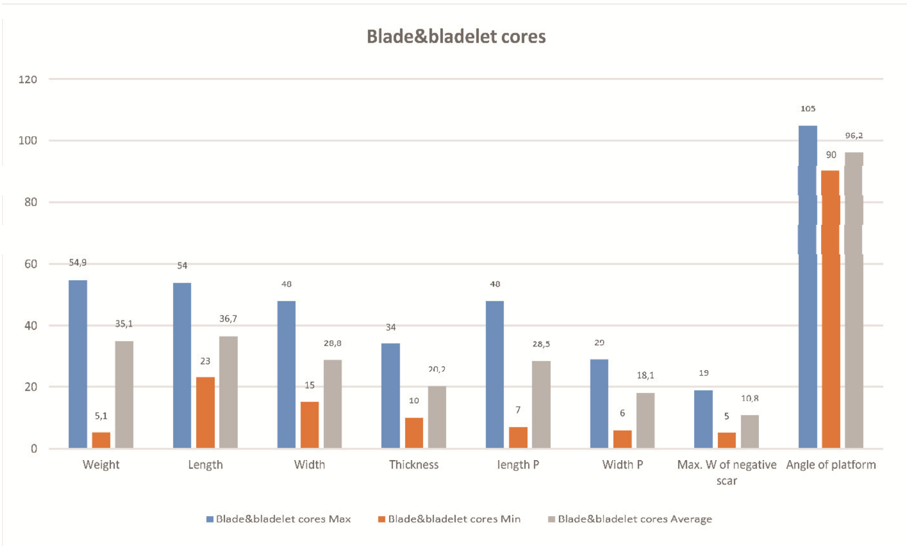
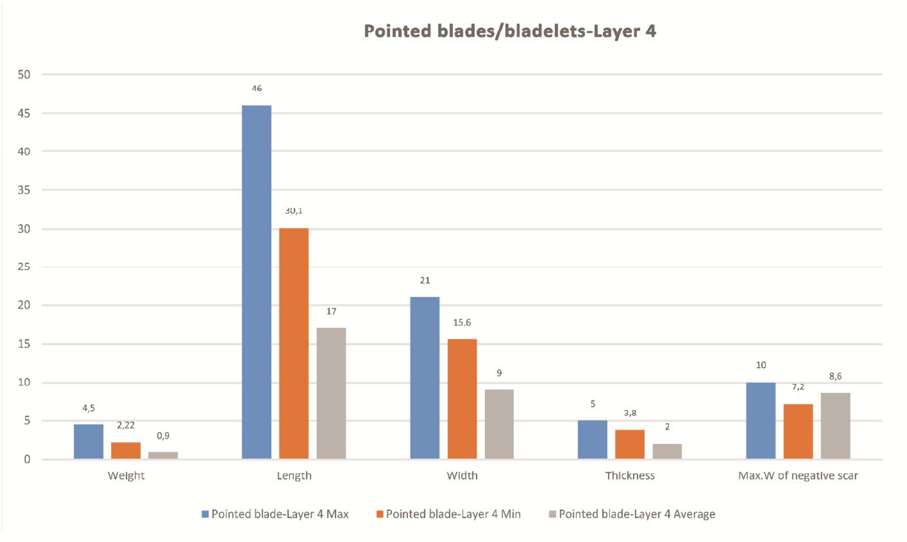


Diagram S1. Comparison of different elements between “Levallois cores vs blade & bladelet cores” within Layers 4 and 5. Created by B.Bazgir.



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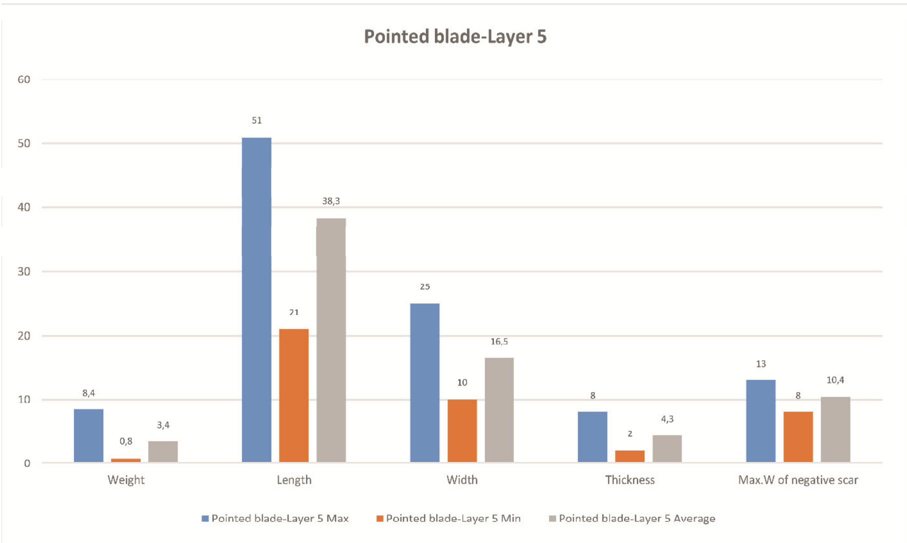


Diagram S2. Comparison of different elements between “retouched points” within Layers 4 and 5. Created by B.Bazgir.

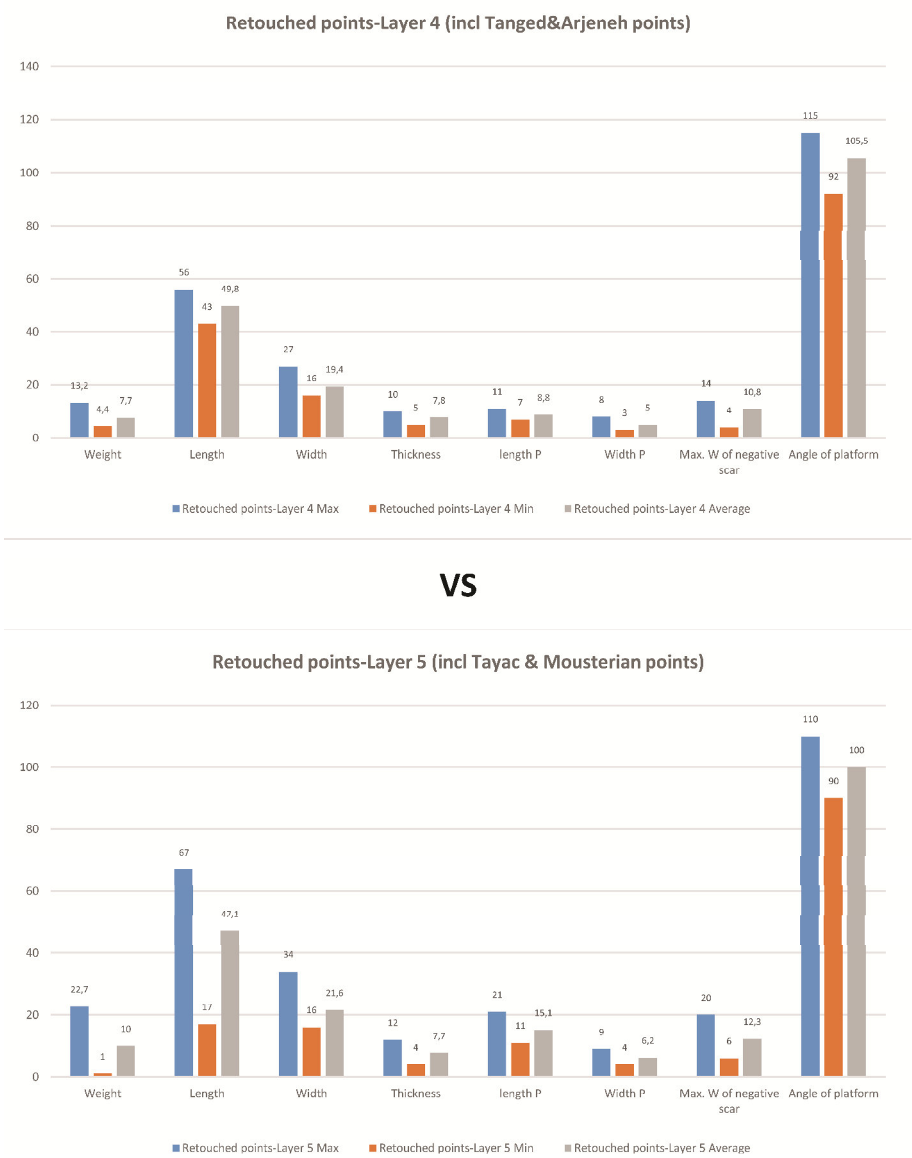
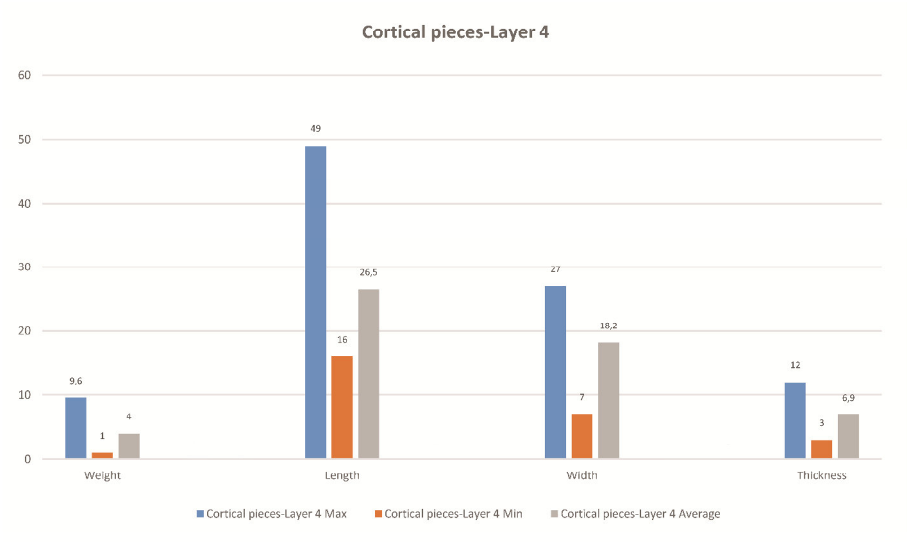


Diagram S3. Comparison of different elements between "pointed blades" within Layers 4 and 5. Created by B.Bazgir.



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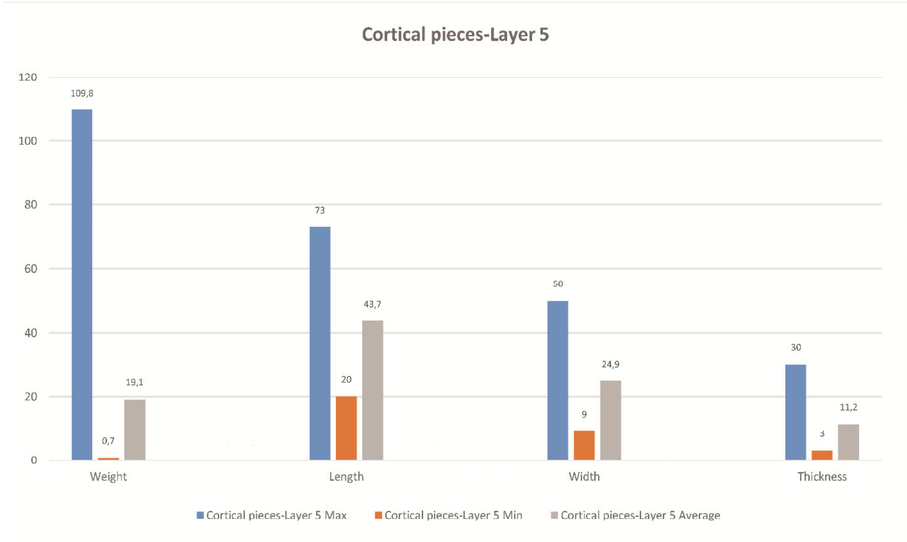
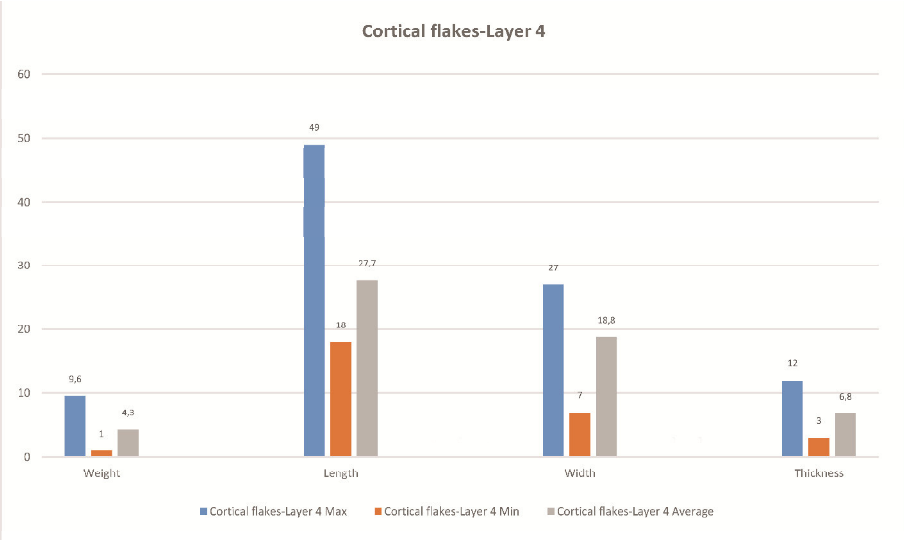


Diagram S4. Comparison of different elements between “cortical pieces” within Layers 4 and 5. Created by B.Bazgir.



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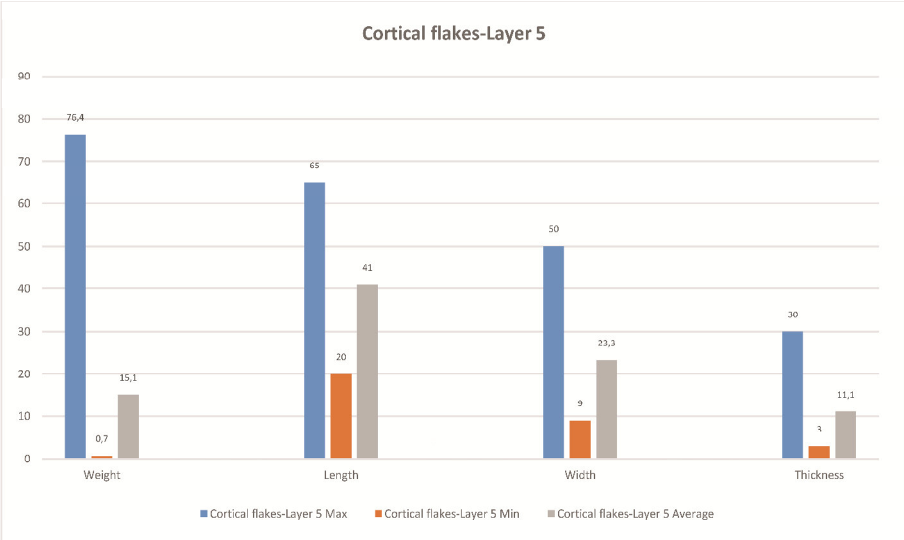

Diagram S5. Comparison of different elements between “cortical flakes” (among the cortical pieces) within Layers 4 and 5. Created by B.Bazgir.

3-4f: Publication 3

Lorena Becerra-Valdivia, Katerina Douka, Daniel Comeskey, Behrouz Bazgir,Nicholas J. Conard, Curtis W. Marean, Andreu Olle, Marcel Otte ,Laxmi Tumung, Mohsen Zeidid, Thomas F.G. Higham. 2017. Chronometric investigations of the Middle to Upper Paleolithic transition in the Zagros Mountains using AMS radiocarbon dating and Bayesian age modelling. Journal of Human Evolution. 109 (2017) 57-69.

In this publication we presented the new archaeological samples achieved for AMS radiocarbon dating from three sites: Kobeh Cave, Kaldar Cave, and Ghar-e Boof (Iran). In addition, we have statistically modelled previously published radiocarbon determinations for Yafteh Cave (Iran) and Shanidar Cave (Iraqi Kurdistan). Our preliminary results from Bayesian modelling suggest that the onset of the Upper Paleolithic in the Zagros Mountains dates to 45,000 - 40,250 cal BP (68.2% probability). Further chronometric data are required to improve the precision of this age range.

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Chronometric investigations of the Middle to Upper Paleolithic transition in the Zagros Mountains using AMS radiocarbon dating and Bayesian age modelling

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ABSTRACT

The Middle to Upper Paleolithic transition is often linked with a bio-cultural shift involving the dispersal of modern humans outside of Africa, the concomitant replacement of Neanderthals across Eurasia, and the emergence of new technological traditions. The Zagros Mountains region assumes importance in discussions concerning this period as its geographic location is central to all pertinent hominin migration areas, pointing to both east and west. As such, establishing a reliable chronology in the Zagros Mountains is crucial to our understanding of these biological and cultural developments. Political circumstance, coupled with the poor preservation of organic material, has meant that a clear chronological definition of the Middle to Upper Paleolithic transition for the Zagros Mountains region has not yet been achieved. To improve this situation, we have obtained new archaeological samples for AMS radiocarbon dating from three sites: Kobeh Cave, Kaldar Cave, and Ghār-e Boof (Iran). In addition, we have statistically modelled previously published radiocarbon determinations for Yafteh Cave (Iran) and Shanidar Cave (Iraqi Kurdistan), to improve their chronological resolution and enable us to compare the results with the new dataset. Bayesian modelling results suggest that the onset of the Upper Paleolithic in the Zagros Mountains dates to 45,000–40,250 cal BP (68.2% probability). Further chronometric data are required to improve the precision of this age range.

1. Introduction

The Middle to Upper Paleolithic (M–UP) transition, dating to between 50,000 and 30,000 years Before Present (BP), marks a pivotal point in late human evolution. It involves the dispersal of anatomically modern humans (AMHs) outside of Africa, the concomitant replacement of Neanderthal populations across the Eurasian record, and the emergence of what is widely termed the ‘Early Upper Paleolithic’ (EUP)—a period often associated with novel symbolic and behaviorally mediated artefacts thought to represent an important change in the cognitive processes of modern humans (see White et al., 1982; Mellars, 1991; Klein, 1995; Bar-Yosef, 2002). It is axiomatic that a reliable chronology is required to compare archaeological sites and material culture across space and place the biological and cultural developments occurring at this

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0047-2484/

time in a proper context. So far, however, the vast majority of Paleolithic archaeological sites that have been investigated chronometrically in any great detail are in Europe. Elsewhere, as is the case with the Zagros Mountains, the archaeological record is not only less abundant, but chronometric data are often absent. Considering that this geographic region acts as a corridor linking Africa to the Levant and Eurasia, establishing a spatio-temporal sequence for the Zagros is crucial. Due to political circumstances within the region and the poor preservation of organic material (bone collagen, in particular) extracted from archaeological sites, however, a clear chronological definition for the M–UP transition has not yet been achieved—very few absolute dates have been published (e.g., Solecki, 1963; Conard and Ghasidian, 2011; Otte et al., 2011; Bazgir et al., 2017; Heydari-Guran and Ghasidian, 2017). In this article, we present new accelerator mass spectrometry (AMS) radiocarbon results from three archaeological sites in the Zagros Mountains and model chronometric data using Bayesian statistics.

2. Background

2.1. Neanderthals and AMHs

Neanderthals and AMHs are hominin groups that are morphologically and genetically distinct from each other. Modern humans evolved in Africa around 200,000 years ago, exited the continent about 60,000–50,000 years ago (or earlier), and reached Eurasia and Australia by about 50,000–45,000 years ago (see Groucutt et al., 2015 for a recent review). Regions adjacent to East Africa—Arabia, Sinai, the Levant, and the Iranian Plateau—record the first modern humans migrating out of this continent and, as 'first contact' areas, hold great paleo-anthropological and archaeological potential. The weight of archaeological and fossil evidence suggests that Neanderthals evolved outside Africa, inhabiting Europe, western Asia, and the Middle East starting from, roughly, 250,000–300,000 years ago (see Hublin, 2009 for a review). Neanderthal occupation ended in Europe at around 41,000–39,000 (95.4% probability) calibrated (cal) BP, strongly suggesting an overlap with AMHs for several thousand years in the region (Higham et al., 2014). Numerous hypotheses have attempted to explain the disappearance of Neanderthals from the archaeological record. These often involve the role of climate (e.g., Finlayson and Carrion, 2007; Jiménez-Espejo et al., 2007) and the perceived superiority of AMHs over Neanderthals in terms of technology, diet, and cognition (e.g., Binford, 1985; Mellars, 1989; Richards and Trinkaus, 2009). Recent ancient genetic research suggests that Neanderthals and AMHs interbred outside of Africa (e.g., Green et al., 2010; Prüfer et al., 2014), resulting in the intrusion of Neanderthal-derived DNA at a proportion of 1.5–2.1% in all non-African modern humans (Prüfer et al., 2014).

2.2. The Zagros Mountains

The Zagros Mountains are a series of parallel mountain ridges interspersed with plains that cross Iran from northwest to southeast, reaching the northeast of Iraq and the southeast of Turkey. The geomorphological setting of the Zagros, a karstic system reaching over 4,000 m above sea level (m.a.s.l.), lends itself to the formation of caves that offer ample opportunities for both paleoenvironmental and archaeological research. Given the physical geography of Iran, bounded in the north and south by mountains, the region has long been considered a potential dispersal corridor for hominins emerging out of Africa. Indeed, Vahdati Nasab et al. (2013) have posited a number of distinct migration routes according to the naturally occurring boundaries in the landscape, including a passageway south of the Zagros Mountains.

2.3. Previous research within the Zagros

Early archaeological research in the Middle East began in the 1920s with researchers such as D.A.E. Garrod, who analysed local lithic assemblages in direct reference to European Paleolithic traditions, i.e., the Mousterian (assigned to Neanderthals and the MP) and the Aurignacian (attributed to AMHs and the UP), according to their typological features (see Garrod, 1928, 1951; Garrod and Bate, 1942). In the 1950s, R. and R. Solecki excavated Shanidar Cave in Iraqi Kurdistan, where a number of Neanderthal individuals were found buried within the MP deposit and the UP material culture was named 'Baradostian' (see Solecki, 1955, 1957, 1960, 1963; Solecki and Solecki, 1993). In addition to this work, C.S. Coon excavated the sites of Bisitun, Tamtama, and Khunik (Coon, 1951); R. Braidwood worked at Warwasi (Braidwood et al., 1961); F. Hole and K. Flannery excavated Kunji, Gar Arjeneh, Pa Sangar, Ghamari, and Yafteh Cave (Hole and Flannery, 1968); and M. Rosenberg investigated Eshkaft-e Gavi (Rosenberg, 1985; Scott and Marean, 2009). In the early 1980s, field investigations in Iran decreased in frequency due to political factors and, as Vahdati Nasab (2011) suggests, the lack of enthusiasm shown by local archaeologists. During this time, workers re-evaluated archaeological collections stored outside of the Zagros. Dibble (1984), for instance, re-studied artefacts from Bisitun, and posited that, in contrast to previous claims concerning the lack of Levallois attributes in Mousterian industries from the Zagros, the assemblage showed a relatively high frequency of the technique. A decade later, through the re-analysis of the Warwasi assemblage, Olszewski and Dibble (1994) proposed the renaming of the Baradostian tradition to 'Zagros Aurignacian', given the perceived similarities with Aurignacian material, and suggested the possibility of an in situ origin for the Aurignacian industry. Beginning in the early 2000s and into the present, joint Iranian-European teams have surveyed, excavated, and reported results from multiple Paleolithic sites across the Zagros Mountains (e.g., Conard et al., 2006; Jaubert et al., 2006; Otte et al., 2007; Conard and Ghasidian, 2011; Bazgir et al., 2014, 2017; Heydari-Guran and Ghasidian, 2017). This new field research may shed light on some of the major questions of interest to prehistorians in this region, including the issue of the origin of the Aurignacian and the Zagros Mountains, as well as the potential presence of mutually distinct and coeval lithic industries within the region during the UP (see Ghasidian et al., 2017).

3. Archaeological sites

We have obtained new chronometric results for Kaldar Cave, Ghār-e Boof, and Kobeh Cave, and analysed previously published radiocarbon dates for the sites of Yafteh and Shanidar Cave (Fig. 1)—all within the Zagros Mountains region. These archaeological sites are briefly described in the following sections.

3.1. Yafteh Cave

Yafteh Cave is located in the Khorramabad region of Lorestan province, western Iran (at 1278 m.a.s.l.; 33°30′30″N, 48°12′41″E), and was excavated in 1965 by Hole and Flannery (1968). The lithic technology at the site has assumed importance in discussions concerning the origin of the Aurignacian tradition due to its morphology and, as reported, similarity to European material (see Otte and Kozłowski, 2004). For this reason, a group from the University of Liège recommenced excavations at the site in 2005 and 2008. Following an analysis of the lithic assemblage, workers

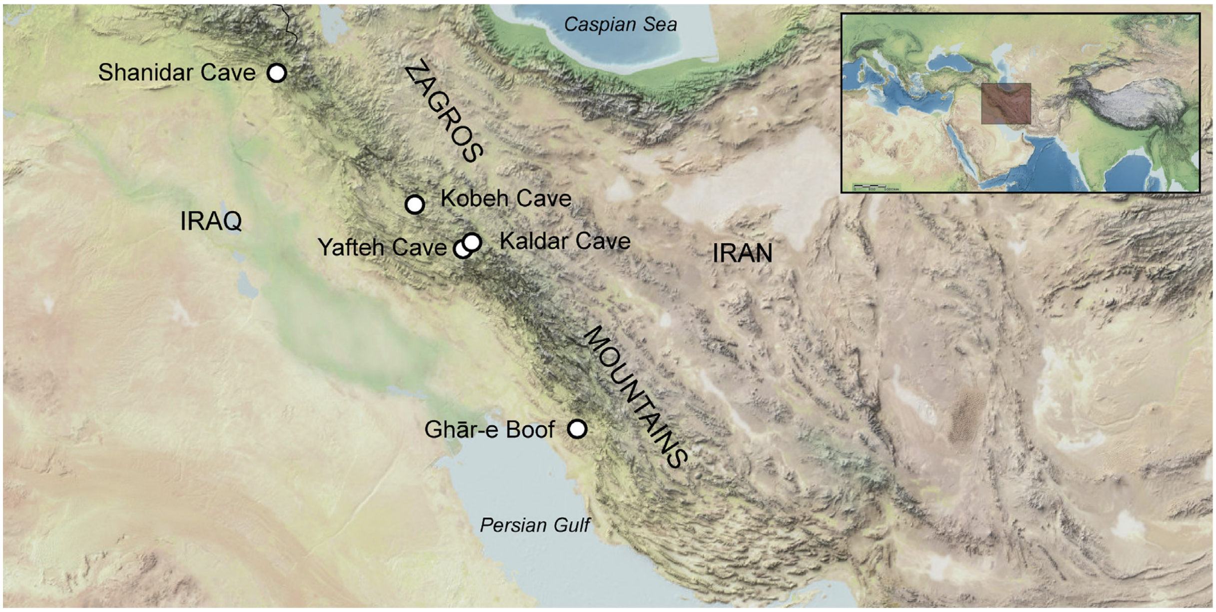

Figure 1. Location of archaeological sites investigated.

proposed an in situ development of the Aurignacian industry in the Zagros Mountains (Otte et al., 2007, 2011).

The stratigraphic sequence in Yafteh Cave contains 19 geological layers distinguished on the basis of soil coloration and texture (Fig. 2). Bedrock was reached during the 2008 season at approximately 3 m in depth. Strata 1–4 correspond to historic and Islamic periods, while evidence for an UP tradition begins near the top of stratum 5 and continues until the bottom of the deposit.

In the 1960s, Hole and Flannery (1968) submitted a series of charcoal samples for radiocarbon dating. The sequence obtained showed age-depth incongruences and wide error margins. Additional charcoal samples were radiocarbon dated following the re-excavation of the site in the 2000s. Based on the new chronometric information, Otte et al. (2011) assigned a date of 33,400 ± 840 BP (Beta-206712) to the beginning of the UP sequence, and 35,450 ± 600 BP (Beta-205844) to the bottom (Fig. 2). All radiocarbon determinations were combined and ordered by Otte et al. (2011) according to depth (Table 1). There is little correspondence between early (1960s) and later (2000s) excavations, however, as Hole and Flannery (1968) did not publish the exact location of their radiocarbon samples within the stratigraphy and the material obtained by Otte et al. (2007) was collected from a different area within the cave.

3.2. Shanidar Cave

Shanidar Cave is situated on Baradost Mountain, Iraqi Kurdistan (44°13′E, 36°′50′N; Solecki, 1957, 1963). The cave is at 731.5 m.a.s.l. or 365.8 m above the Greater Zab River (Solecki, 1955). It has a length of 40 m, a maximum width of 53.34 m, and a total surface area of 1200 m^2 (Solecki, 1955, 1957, 1963). Shanidar Cave was originally excavated by R. Solecki from 1951 to 1960, in four separate seasons (years 1951, 1953, 1956–1957 and 1960; Solecki, 1955, 1957, 1960, 1963). After a long hiatus, excavations recommenced in recent years under G. Barker, University of Cambridge.

In 1951, Solecki began excavations with a sounding of 4.47 by 6.10 m, reaching 7.62 m in the deepest section. This was enlarged in 1953 to an area of 6.10 by 12.9 m, where bedrock was reached at a maximum depth of 13.41 m in the western portion of the sounding, and to 20 by 7.75 m in the 1957 season. Solecki divided the excavation area into 44 vertical levels (Solecki and Solecki, 1993) and identified four distinct archaeological layers—A, B, C, and D (Solecki, 1957). Layer A extends from modern times to the Neolithic, while Layer B contains no evidence of agriculture, animal domestication, or pottery making. Following Layer B, Solecki noted a gap in the stratigraphic sequence of a suggested span of 17,000 years, a period during which the cave was apparently left unoccupied. The sequence continues with Layer C, which marks an UP occupation. Layer D, sealed from the above deposit by rockfall within levels 14 and 15 (4.27–4.52 m from the surface), corresponds to the MP and a Neanderthal occupation (Solecki, 1957; Solecki and Solecki, 1993). Within this layer, the remains of 10 Neanderthal individuals were found (see Solecki, 1957, 1963, 1975; Trinkaus, 1978; Trinkaus and Zimmerman, 1982; Solecki and Solecki, 1993; Cowgill et al., 2007) (Fig. 3).

The chronology of Shanidar Cave, in Solecki's time, was fixed by radiocarbon dates provided by four different laboratories (Table 2; Solecki, 1963). Apart from presenting some of these dates in publications, no further details concerning the materials or methods used in the dating process have been provided. Based on samples W-667 and W-179, Layer B1 was dated to 10,300 ± 300 BP and B2 to 12,000 ± 400 BP (Solecki, 1963). The top portion of Layer C was dated to 28,700 ± 700 BP (sample W-654) and the bottom to 35,080 ± 500 BP (GrN-2549), while material taken from 5.1 m below the surface yielded a determination of 46,000 ± 1500 BP (GnN-2527) for Layer D (Solecki, 1963). Additionally, several obsidian samples from Layers B and C were analysed using the obsidian hydration method (Evans and Meggers, 1960; Solecki, 1963). These determinations do not show a congruent age-depth pattern.

3.3. Kaldar Cave

Kaldar Cave is located in the Khorramabad Valley, Lorestan Province, western Iran (48°17′35″E, 33°33′25″N). The cave sits at 1290 m.a.s.l., has a length of 16 m, a width of 17 m, and is 7 m high. An international team initially investigated Kaldar Cave during 2012, along with three other archaeological sites (Bazgir et al., 2014). This initial effort consisted of the opening of a 1 m^2 test pit at the very centre of the cave, which revealed a 1.5 m

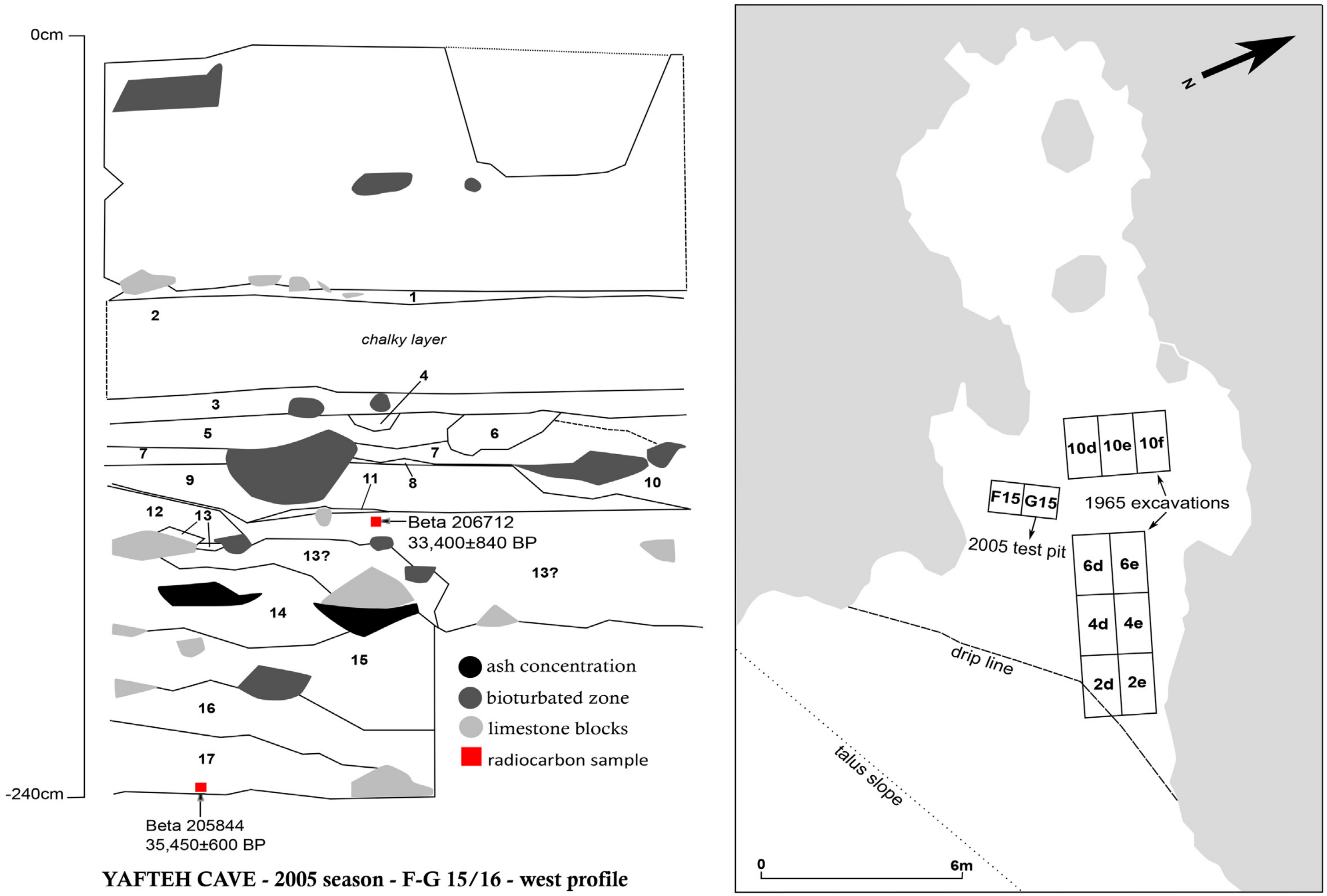

Figure 2. Schematic of the stratigraphy uncovered during the 2005 season (F-G 15/16, west profile) and floor plan at Yafteh Cave (modified from Otte et al., 2007).

Table 1
Published radiocarbon determinations for Yafteh Cave ordered by depth after Otte et al. (2011).

Laboratory number	Collected (year)	Depth (below datum; cm)	Radiocarbon date (BP)
Beta-206711	2005	125	24,470 ± 280
Beta-206712	2005	150	33,400 ± 840
GX-711	1965	200	34,800 + 2900/−4500
GX-710	1965	201	32,500 + 2400/−3400
SI-332	1965	201	29,410 ± 1150
Beta-245910	2008	210.5	33,800 ± 330
SI-333	1965	212	30,860 ± 3000
Beta-251058	2008	213	32,190 ± 290
Beta-251062	2008	213.5	33,160 ± 240
Beta-251059	2008	226.5	32,900 ± 290
Beta-251060	2008	234	33,260 ± 300
Beta-245908	2008	236	22,430 ± 310
Beta-205844	2005	240	35,450 ± 600
Beta-245909	2008	245	33,330 ± 310
SI-336	1965	250	21,000 ± 800
Beta-251061	2008	251	31,120 ± 240
Beta-245913	2008	258.5	34,360 ± 340
Beta-245907	2008	260	32,770 ± 290
GX-709	1965	260	38,000 + 3400/−7500
Beta-245911	2008	266.5	33,520 ± 330
Beta-24912	2008	273	34,160 ± 360
SI-334	1965	278	31,760 ± 3000
GX-708	1965	280	>36,000
GX-707	1965	280	34,300 + 2100/−3500
SI-335	1965	285	>40,000
GX-706	1965	290	>35,600

stratigraphic sequence containing multiple cultural levels. Following field observations, excavators realised that Kaldar Cave contained a better stratigraphic sequence than the other sites excavated. As such, a second excavation designed to obtain samples for dating and gain a better understanding of stratigraphic associations commenced in 2014. During this season, excavators opened a 3 × 3 m trench near the cave entrance and location of previous test pits (squares E5, E6, E7, F5, F6, F7, G5, G6 and G7) using 5 cm spits and recorded all findings within a three-dimensional (3-D) grid. The trench exposed an approximately 2 m section of sedimentary deposit characterised by five main cultural layers (see Fig. 4). Layers 1 to 3 (including sub-layers 4 and 4II) contain multiple phases dating to the Holocene; Layer 4 (including sub-layers 5, 5II, 6 and 6II), with its associated lithic technology, e.g., points, blades, and twisted bladelets, corresponds to the UP; and Layer 5 (including sub-layers 7 and 7II) contains a characteristic MP lithic assemblage with Levallois elements (Bazgir et al., 2014). So far, no chronometric data are available for Layer 5 (Bazgir et al., 2017).

3.4. Ghār-e Boof

Ghār-e Boof, a small cave with a total surface area of 100 m^2, is situated in the Dasht-e Rostam region of Fars Province, southern Iran, at 905 m.a.s.l. (Conrad and Ghasidian, 2011). The site was excavated by the Tübingen Iranian Stone Age Research Project in 2006, 2007, and 2015. The predominant lithic component in the UP are bladelets belonging to a technocomplex termed 'Rostamian' by the excavators (Conard and Ghasidian, 2011; Ghasidian, 2014). A survey of 90 other caves and rockshelters of the Dasht-e Rostam yielded Rostamian assemblages but, so far, excavations have only been conducted at Ghār-e Boof. The Rostamian tradition consists of a specialised mode of lithic reduction that appears to be absent from contemporary sites along the Zagros Mountains, bearing no techno-typological resemblance to Aurignacian or Baradostian industries. As such, it is hypothesised that the Rostamian technocomplex evolved locally in the southern Zagros. This documents a high degree of cultural diversity in the region during the UP (Conard and Ghasidian, 2011; Ghasidian, 2014; Ghasidian et al., 2017).

The excavation area (2 × 9 m) at Ghār-e Boof extends from the drip line to the back of the cave on a north–south axis. An elevation datum was assigned to the z-axis at an elevation of 8 m, and bedrock was reached at a depth of 5.5 m in the rear. Archaeological horizons (AH) were identified as such by material culture, soil coloration, and other distinctive features (Fig. 6). At the top of the sequence, AH I and II correspond to Holocene silts and ash deposits. AH III corresponds to the UP as identified through a lithic assemblage dominated by bladelets and bladelet cores. The stratigraphic sequence ends in unit 6/2 with Geological Horizon (GH) 4, containing AH IV, IVa, and IVb, also corresponding to the UP. The most recent excavation season, in 2015, reached MP deposits in the central part of the cave, but more fieldwork is required to obtain statistically significant artefact assemblages from these basal layers.

Radiocarbon dating of two seed samples (OxA-25783 and OxA-25785) was previously undertaken at the Oxford Radiocarbon Accelerator Unit (ORAU), using a pre-treatment method designed to minimise the destruction of material. These samples—legume remains found within AH IIIb at depths of 4.90 and 4.82 m, respectively—yielded dates of 33,850 ± 360 and 34,900 ± 650 BP. Additional material was submitted for radiocarbon dating at the Leibnitz-Labor Laboratory, University of Kiel (Conard and Ghasidian, 2011; Ghasidian, 2014). Results obtained from two vetches (*Vicia ervilia*) from AH IV, the oldest stratum, were measured at 33,060 ± 270 BP and 36,030 ± 390 BP (see Fig. 5).

3.5. Kobeh Cave

Kobeh is a small cave (7 × 12 m) located near the capital of Kermanshah province, western Iran, in the west-central section of Zagros Mountains (47°10′8.25″E, 34°25′47.96″N; Marean and Kim, 1998). It is situated at an altitude of 1300 m.a.s.l. near the Tang-i-Knisht Valley. Fieldwork led by B. Howe began at the site in 1959, with a 2 × 2.5 m test pit (Marean and Kim, 1998). From the surface, the entire excavated sequence extends to a depth of 3.2 m, where a rockfall event overlies a separate, seemingly sterile horizon. Prior to a depth of 1.6 m, the presence of sporadic ceramic fragments and faunal remains was reported (Marean and Kim, 1998). Below this depth, layers P, Q, and R correspond to the terminal MP and include lithic and faunal material—the latter showing bone surface modification (Marean and Kim, 1998).

4. Materials and methods

Bone samples from Kobeh Cave (n = 14) and Ghār-e Boof (n = 42) were pre-screened for collagen preservation prior to sampling for radiocarbon dating (after Brock et al., 2010a). This step involved measuring the percent nitrogen (%N) in ~5 mg of whole bone powder (drilled and placed into a tin capsule) in a continuous flow isotope ratio mass spectrometer (Sercon 20/20), consisting of a CHN elemental analyser (Carlo-Erba NA, 2000) coupled to a gas source IRMS. Samples which show values lower than ~0.75 %N are not usually passed on to AMS radiocarbon dating, as they are not likely to contain sufficient collagen (<1% weight). All other materials—three seed samples from Ghār-e Boof, seven charcoal samples from Kaldar Cave, and one riverine snail from Ghār-e Boof—underwent the appropriate chemical pre-treatment method designed to remove exogenous carbon. These included phosphoric acid dissolution, acid-base-wet oxidation/stepped combustion (ABOx-SC), and modified versions of ABOx-SC employed to avoid

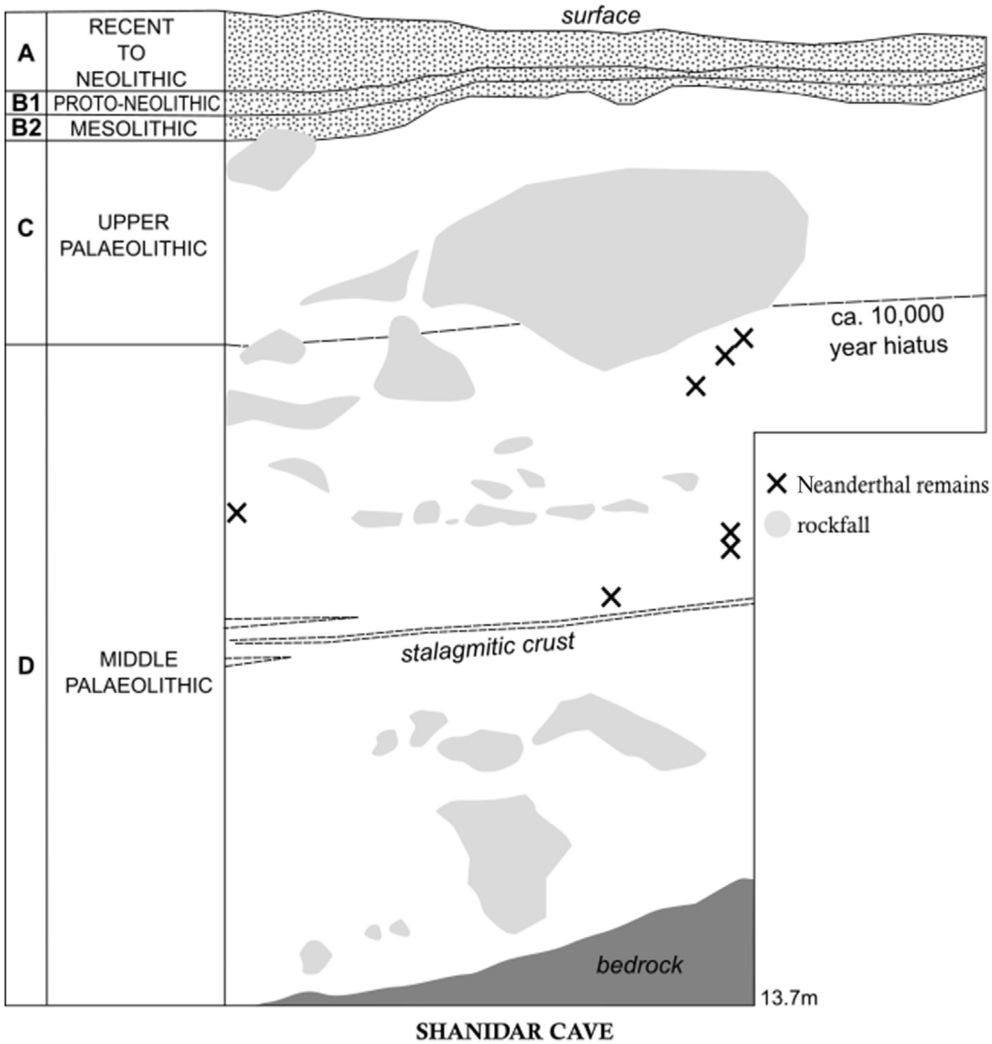

Figure 3. Schematic of the stratigraphy at Shanidar Cave (redrawn from Solecki, 1963).

Table 2
Published radiocarbon determinations for Shanidar Cave. This list reflects available information from the published sources reviewed.

Laboratory number	Archaeological context	Date (BP)	Published source
W-667	Layer B1	10,600 ± 300	Solecki, 1963
W-179	Layer B2	12,000 ± 400	Solecki, 1963; Hole and Flannery, 1968
W-654	Layer C	28,700 ± 700	Solecki, 1963; Hole and Flannery, 1968
W-178	Layer C (top); square S3W1; 3.05 m deep	29,500 ± 1500	Solecki, 1955; Hole and Flannery, 1968
W-180	Layer C	>34,000	Hole and Flannery, 1968
W-650	Layer C	33,300 ± 1000	Hole and Flannery, 1968
GrN-1830	Layer C	33,900 ± 900	Hole and Flannery, 1968
GrN-1494	Layer C	34,400 ± 420	Hole and Flannery, 1968
GrN-2016	Layer C	35,400 ± 600	Hole and Flannery, 1968
GrN-2015	Layer C	35,540 ± 500	Hole and Flannery, 1968
GrN-2549	Layer C	35,080 ± 500	Solecki, 1963
GrN-2527	Layer D	46,900 ± 1500	Solecki, 1963; Hole and Flannery, 1968
GrN-1495	Layer D	50,600 ± 3000	Hole and Flannery, 1968

sample failure (see Brock et al., 2010b, for a detailed description of routine pre-treatment protocols used). ABOx-SC was chosen over the routine acid-base-acid (ABA) method, as it has been shown to remove contaminants more efficiently from Paleolithic-aged charcoal samples, often yielding significantly older dates (e.g., Bird et al., 2003; Brock and Higham, 2009; Higham et al., 2009a, 2009b; Douka et al., 2010; Wood et al., 2012).

Following pre-treatment, dried samples were weighed and approximately 3–3.5 mg of material was combusted in the same CF-IRMS system employed for bone collagen pre-screening. Gaseous CO_2 produced during acid dissolution was inserted directly. After the measurement of carbon stable isotopes, the CO_2 was collected and transferred to pre-conditioned rigs containing a 2.0–2.5 mg iron catalyst and H_2 added at a ratio of $2.2H_2:CO_2$. These were heated at 560 °C for 6 h (Dee and Ramsey, 2000). Graphite targets were made with approximately 0.8 mg–1.8 mg of carbon, depending on the yield of each sample. Radiocarbon measurement was undertaken in a High Voltage Engineering Europa (HVEE) 2.5 MeV accelerator mass spectrometer. Radiocarbon determinations were calculated according to the conventions outlined in Stuiver and Polach (1977).

The calibration and Bayesian modelling of radiocarbon determinations was undertaken using the OxCal 4.3 platform (Bronk Ramsey, 2009a, 2009b) and the IntCal13 calibration curve (Reimer et al., 2013). Radiocarbon dates in a Bayesian model are expressed in terms of a probability density function (PDF) through use of Markhov Chain Monte Carlo simulation approaches, which finds the highest probability distribution for these as weighed towards known archaeological information for each site. The statistical

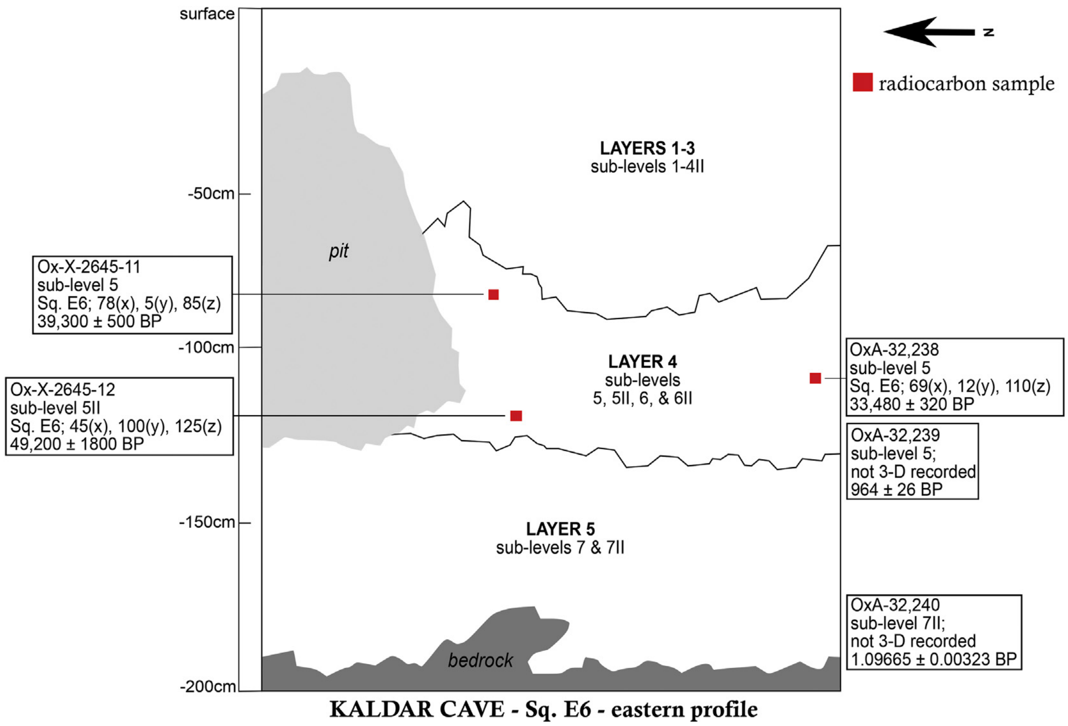

Figure 4. Schematic of the stratigraphic sequence at Kaldar Cave (SQ E6, eastern profile), showing the location of samples that were AMS radiocarbon dated.

analysis is based on the assumption that a given chronological sequence is divided into separate units of time, called 'Phases', which contain radiocarbon dates. Phases are constrained by 'boundaries' which serve as mathematical functions and produce PDFs estimating the start and end of each Phase. By assigning each likelihood a prior probability of being an outlier, its influence on a given model is down-weighted, allowing for flexibility. As such, all dates modelled here were ascribed a 5% prior probability of being an outlier within the General t-type Outlier Model (Bronk Ramsey, 2009b).

5. Results

None of the faunal bone samples tested for %N reached the threshold of 0.75 (Table 3). These results suggested that no samples contained enough collagen for AMS radiocarbon dating, thus none was passed on for further pre-treatment.

Of seven charcoal samples processed, only five from Kaldar Cave passed chemical pre-treatment and were AMS dated (Tables 4 and 5; these results are also noted in Bazgir et al., 2017). Of these, two yielded modern dates incongruent with their position in the stratigraphy. This is likely because the two charcoal samples were general finds and their exact location within the stratigraphy is not known (see Table 4; Fig. 4). Considering that only three reliable dates were obtained for Kaldar Cave, no modelling was undertaken. From Ghār-e Boof, two out of four samples analysed (three seeds and one riverine snail) passed pre-treatment and were AMS dated (Tables 4 and 5; Fig. 6). The snail sample (OxA-32390), collected from AH IV, yielded a comparatively younger date than the seed taken from AH III (OxA-X-2633-54) and was duly identified as an outlier in the resulting model (at 91% probability; Fig. 5). This age-depth discrepancy has a number of potential explanations. The two most parsimonious are i. post-depositional mixing within the sequence, e.g., bioturbation, or ii. modern carbon contamination resulting in an underestimation of the true age. The first explanation cannot be ruled out. The second applies to the carbonate if the presence of recrystallized calcite is detected or other sources of modern carbon are somehow introduced during laboratory procedures. In this case, both are unlikely as the snail shell was tested using geological staining techniques (Friedman, 1959) prior to acid dissolution and found to be aragonitic, while the procedural blank that accompanied it during dating procedures showed no significant levels of modern carbon contamination (fM = 0.00001 ± 0.00023).

The Bayesian model created for this site incorporates previously published radiocarbon determinations (Ghasidian, 2014) and the two AMS dates obtained, yielding a start boundary for the UP at 41,950–39,850 cal BP (68.2% probability; Fig. 5). The model identified two outliers (KIA-32763 and OxA-32390) and resulted in bimodal distributions, especially for the end of AH III.

For Yafteh Cave, a Bayesian model incorporating radiocarbon determinations published by Otte et al. (2011) and their respective depths in a sequence yields a date boundary for the beginning of the UP at 38,850–38,000 cal BP (68.3% probability; Fig. 7). Beta-251061, Beta-205844, and Beta-206711 are identified as outliers at likelihoods of 100%, 90%, and 100%, respectively. The radiocarbon determinations obtained by Hole and Flannery (1968) were not included in this model as they show wide error margins and, as discussed, their stratigraphic relationship with the samples obtained in the 2000s is unknown.

For Shanidar cave, modelling the radiocarbon determinations obtained in the 1960s (Solecki, 1963; Hole and Flannery, 1968) for Layers B1, B2, C, and D, results in a PDF for the M–UP transition at 43,200–39,600 cal BP (68.2% probability) with no outliers (Fig. 8).

The incorporation of PDFs generated for the onset of the UP for Yafteh Cave, Ghār-e Boof, and Shanidar Cave into a single Bayesian model, results in a start boundary for the UP in the Zagros Mountains dating to 45,100–40,350 (68.2% probability) cal BP (Fig. 9).

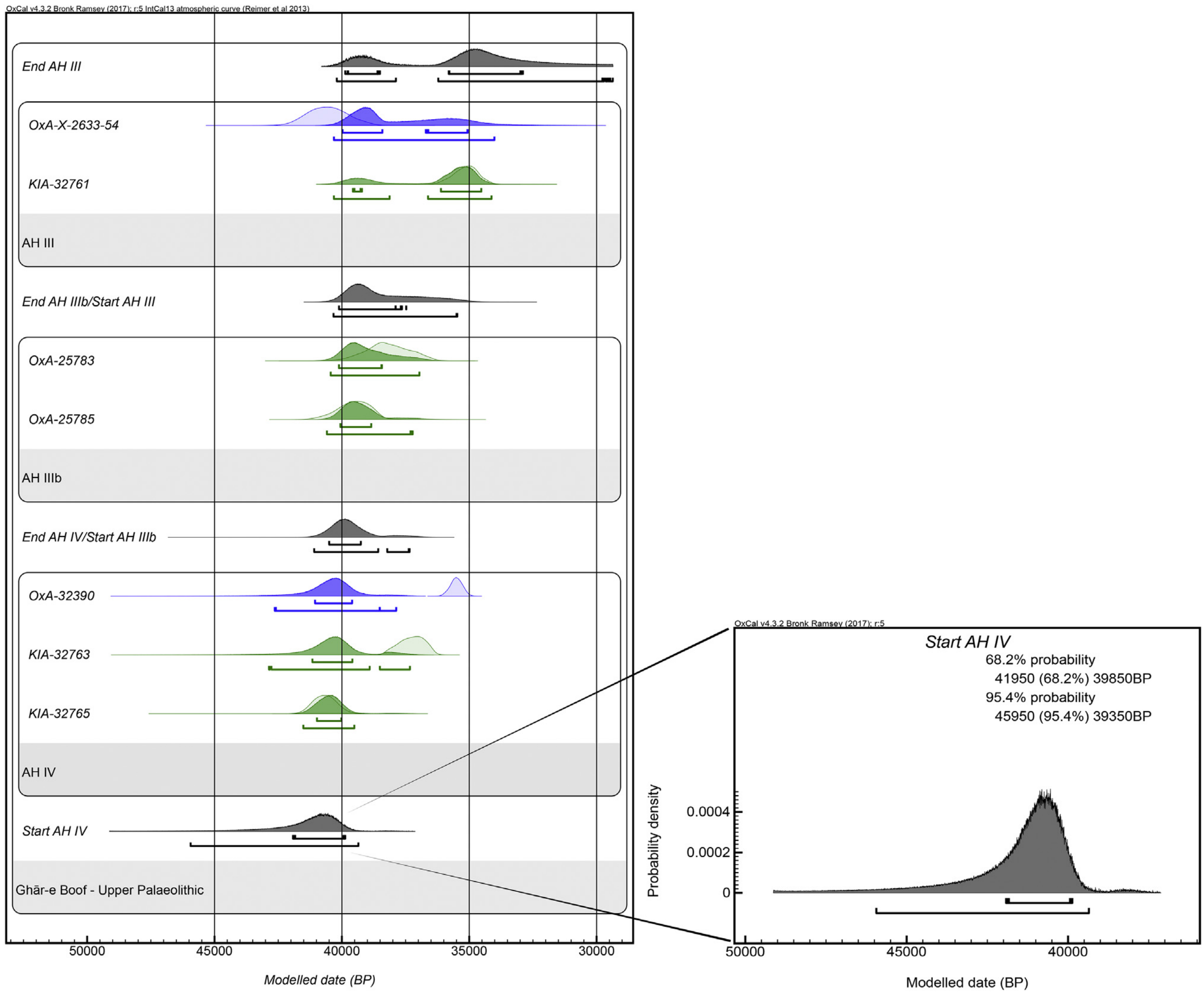

Figure 5. Bayesian model of radiocarbon dates for the Upper Paleolithic sequence at Ghār-e Boof, including those published by Ghasidian (2014; in green), and the two OxA dates obtained (in blue). This model has three separate phases corresponding to AHs IV, IIIb, and III. The boundary for the start of AH IV corresponds to the onset of the Upper Paleolithic at the site. OxCal CQL code is provided in Supplementary Online Material (SOM). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

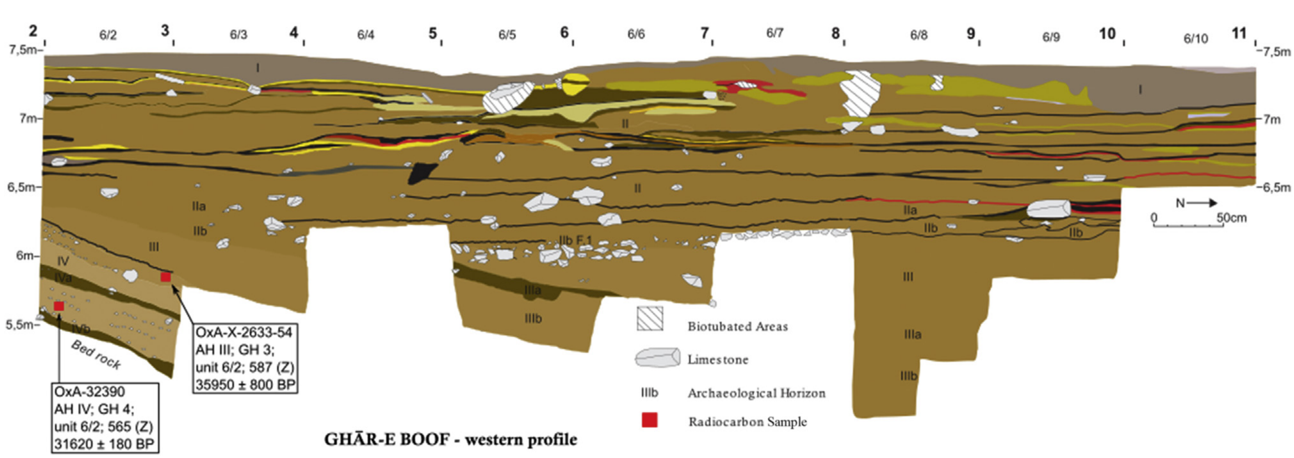

Figure 6. Schematic of the stratigraphic sequence at Ghār-e Boof (western profile), showing the location of samples which were AMS radiocarbon dated through this investigation. After Conard and Ghasidian, 2011, Figure 7.

Table 3
Pre-screening results (%N) of faunal bone samples from Kobeh Cave (KoC) and Ghār-e Boof (GB). Sample references followed by either 'A' or 'B' refer to sub-samples within the same bone fragment. The results suggest a uniformly low level of remaining collagen in the bones.

Site	Sample reference	Combusted (wt; mg)	N (µg)	%N (wt)
KoC	675	4.97	5.02949	0.101
KoC	684	5.14	6.27834	0.122
KoC	690A	4.99	5.37038	0.108
KoC	690B	5.13	4.92662	0.096
KoC	702	4.95	4.69297	0.095
KoC	1988	5.06	6.00349	0.119
KoC	8096	5.7	8.04789	0.141
KoC	8217	4.97	5.84302	0.118
KoC	8642	5.08	6.00941	0.118
KoC	8968	5.08	15.11011	0.297
KoC	3672	5.11	3.69197	0.072
KoC	3680A	5.07	17.27945	0.341
KoC	3680B	4.93	13.16061	0.267
KoC	3695	4.9	7.55116	0.154
KoC	3818	4.81	4.92294	0.102
KoC	3827	4.8	5.90319	0.123
GB	1A	2.61	5.59388	0.21
GB	1B	2.79	5.99152	0.21
GB	2A	2.46	5.05467	0.21
GB	2B	2.48	5.36492	0.22
GB	3A	2.73	4.61503	0.17
GB	3B	2.58	3.67806	0.14
GB	4A	2.5	6.13677	0.25
GB	4B	2.67	7.37776	0.28
GB	5A	2.99	5.58735	0.19
GB	5B	2.84	5.69284	0.2
GB	6A	3	6.07218	0.2
GB	6B	2.78	7.05446	0.25
GB	7A	2.35	4.9019	0.21
GB	7B	2.46	5.50677	0.22
GB	8	2.79	7.28358	0.26
GB	9	2.93	5.30434	0.18
GB	10A	2.82	6.60423	0.23
GB	10B	2.8	6.23539	0.22
GB	11A	2.69	8.31874	0.31
GB	11B	2.76	7.28077	0.26
GB	12A	3.03	7.33149	0.24
GB	12B	2.45	3.35461	0.14
GB	13	2.28	5.73843	0.25
GB	14	2.82	5.1007	0.18
GB	15	2.98	5.79644	0.19
GB	16	2.8	3.96831	0.14
GB	17	2.71	7.74739	0.29
GB	18	2.78	6.59087	0.24
GB	19	2.38	6.11892	0.26
GB	20	3.22	5.60614	0.17
GB	21	2.94	5.1426	0.17
GB	22	2.67	5.21032	0.2
GB	23	2.98	7.22746	0.24
GB	24	3.17	7.2795	0.23
GB	25	2.72	4.82615	0.18
GB	26	2.96	6.71204	0.23
GB	27	2.26	3.94588	0.17
GB	28	2.5	5.27486	0.21
GB	29	2.99	5.20558	0.17
GB	30	2.36	4.57249	0.19
GB	31	3.2	2.65732	0.08
GB	32	2.71	6.20176	0.23
GB	33	2.63	3.19625	0.12
GB	34	3.14	4.09168	0.13
GB	35	2.96	4.26613	0.14
GB	36	3.19	4.00298	0.13
GB	37	3.22	5.21662	0.16
GB	38	2.91	3.52456	0.12
GB	39	2.97	4.72232	0.16
GB	40	3.2	3.30962	0.1
GB	41	2.72	5.75578	0.21
GB	42A	3.17	2.26344	0.07
GB	42B	2.59	1.5701	0.06

6. Discussion

Based on the small number of new determinations which we were able to obtain, it is clear that further work is required if we are to obtain robust site chronologies and increase the temporal resolution of the M–UP transition in the Zagros Mountains. We encountered severe difficulties with the radiocarbon dating of bone from the region, and our pre-screening efforts showed that bones containing collagen are rare. Collagen is affected by the combined influences of post-depositional temperature, moisture content, bacterial presence and site pH, which together cause the loss of collagen through diagenetic processes (see Collins et al., 2002; Hedges, 2002). Under certain circumstances, this reduces the number of bones from a given site which are suitable for dating, restricting the potential to reliably date an archaeological sequence. Attempting to date material from archaeological sites known to yield poorly preserved bones with low collagen content is, therefore, an inefficient use of time and resources. Unfortunately, %N results for Kobeh Cave and Ghār-e Boof suggest that this might very well be the case for the Zagros Mountains—no pre-screened samples passed 0.4 %N, showing that collagen preservation was exceptionally poor. The data are not without value, however, as they do suggest that chronometric investigations in the region ought to focus on other types of organic material. The radiocarbon dating of charcoal, for example, will most likely produce a higher number of AMS radiocarbon dates. It is important to emphasise, however, that in the dating of Paleolithic-aged charcoal, rigorous pre-treatment methods should be employed in order to obtain robust results. The routinely used ABA protocol has been shown to consistently underestimate the age of 'old' charcoal when compared to ABOx-SC. The younger date range obtained for the UP start boundary at Yafteh Cave, in comparison to the other sites investigated, is likely to be an underestimate based on the use of ABA techniques in the preparation of previously obtained dates. If additional material was secured in the future, the use of more rigorous pre-treatment protocols would likely provide a more reliable, probably older, chronology for the site.

It is important that we continue our efforts to improve the chronology of Zagros sites due to the archaeological importance of the region and the likely elucidation of spatio-temporal dynamics in hominin dispersal. Future chronometric investigations focused on terminal MP sequences within the region, for instance, will help to determine the nature of the transition and whether it involved a direct replacement of Neanderthals by modern humans or not. Therein lies the importance of archaeological and chronometric research in sites like Kaldar, Ghār-e Boof, and Shanidar Cave, which contain both Middle and Upper Paleolithic sequences.

7. Conclusion

High-precision AMS radiocarbon dates were obtained for the Upper Paleolithic layers of Kaldar Cave and Ghār-e Boof—key archaeological sites within the Zagros Mountains. These, along with the statistical analysis of previously published radiocarbon determinations for the sites of Yafteh Cave (Iran) and Shanidar Cave (Iraqi Kurdistan), allowed us to build preliminary age models using Bayesian modelling methods with OxCal 4.3. The date boundary obtained for the start of the UP in the Zagros Mountains (40,000–45,250 cal BP at 68.2% confidence) is similar to estimates for the start of the UP in other parts of Eurasia, including the Levant (e.g., Douka, 2013) and Europe (e.g., Wood et al., 2014), but does not significantly predate them. Pre-screening efforts focused on faunal bone remains demonstrated that for Kobeh Cave and Ghār-e Boof,

Table 4
Details of samples from Kaldar Cave (KaC) and Ghār-e Boof (GB) which passed chemical pre-treatment and were AMS radiocarbon dated.

Site	Sample reference	Material	Species	Archaeological context
KaC	723	charcoal	*Prunus* cf. *amygdalus*	Trench (T) 1; Level 4, sub-level 5; SQ E6; 69 (X), 12 (Y), 110 (Z)
KaC	non-provided; 'A'	charcoal	*Quercus* sp. deciduous	T1; Level 4, sub-level 5; SQ G6
KaC	non-provided; 'B'	charcoal	*Quercus* sp. deciduous	T1; Level 5, sub-level 7II; SQ F7
KaC	274	charcoal	*Prunus* cf. *amygdalus*	T 1; Level 4, sub- level 5; SQ E7; 78 (X), 5 (Y), 85 (Z)
KaC	869	charcoal	*Prunus* cf. *amygdalus*	T1; Level 4, sub-level 5II; SQ E6; 45 (X), 100 (Y), 125 (Z)
GB	find no. 206	seed	*Lathyrus* sp.	AH III; GH 3; unit 6/2; 587 (Z)
GB	find no. 236	snail	*Theodoxus* sp.	AH IV; GH 4; unit 6/2; 565 (Z)

Table 5
AMS radiocarbon dates for the sites of Kaldar Cave (KaC) and Ghār-e Boof (GB).

Site	Sample reference	ORAU Lab code	$\delta^{13}C$ (‰)	Radiocarbon date (BP)	Calibrated date (95.4% probability)
KaC	723	OxA-32238	−23	33,480 ± 320	38,650–36,750 cal BP
KaC	'A'	OxA-32239	−23.1	964 ± 26	1000–1200 AD
KaC	'B'	OxA-32240	−27.1	1.09665 ± 0.00323	1850–1950 AD
KaC	274	OxA-X-2645-11	−23.4	39,300 ± 550	44,200–42,350 cal BP
KaC	869	OxA-X-2645-12	−24.5	49,200 ± 1800	54,400–46,050 cal BP
GB	find no. 206	OxA-X-2633-54	−21.3	35,950 ± 800	42,050–38,950 cal BP
GB	find no. 236	OxA-32390	−6.7	31,620 ± 180	36,000–35,000 cal BP

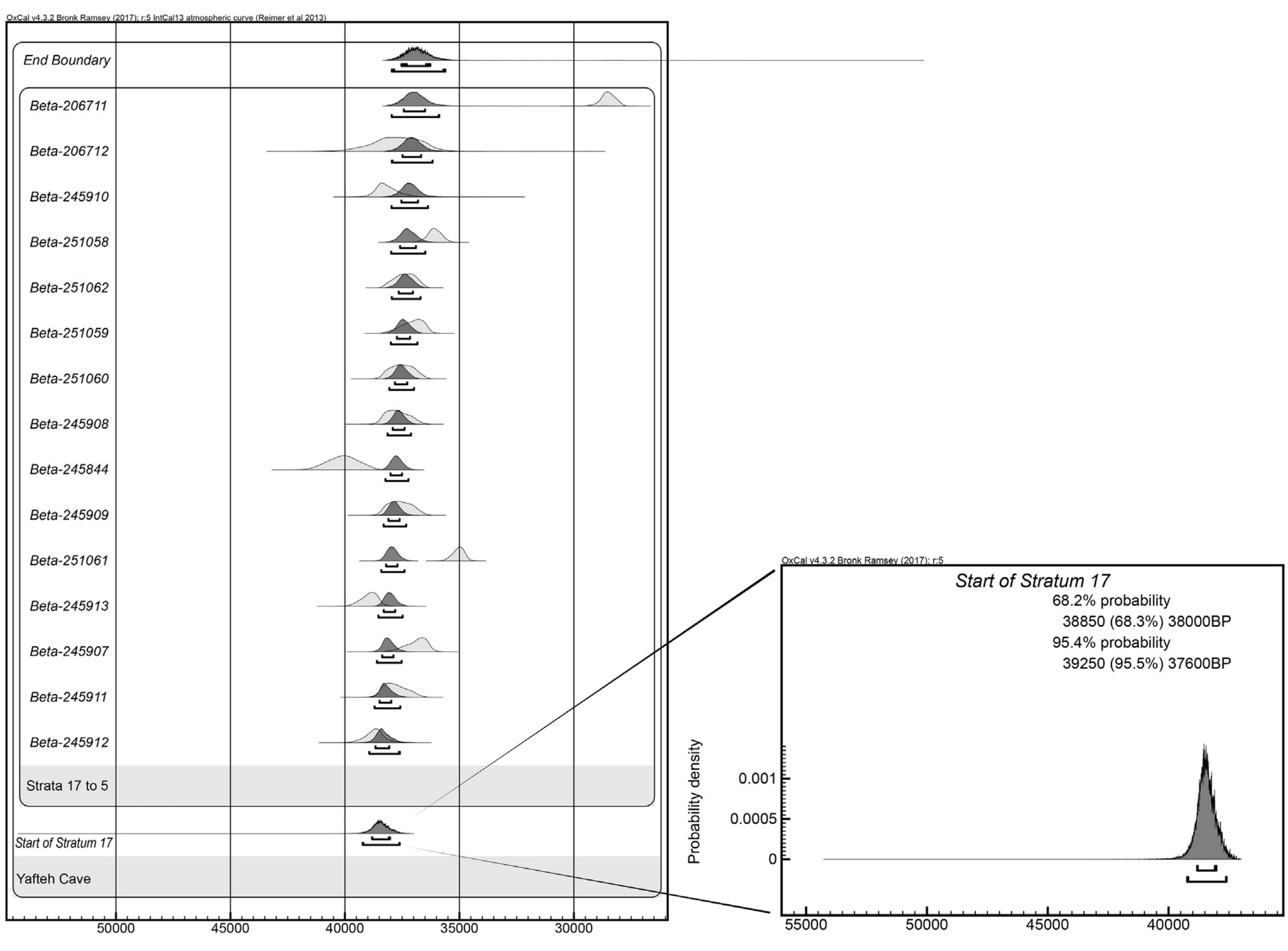

Figure 7. Bayesian model of radiocarbon dates for the Upper Paleolithic sequence at Yafteh Cave, including those obtained in the 2000s as published by Otte et al. (2011). The boundary for the start of stratum 17 corresponds to the onset of the Upper Paleolithic at the site. OxCal CQL code in SOM.

collagen preservation is low and yields are insufficient for radiocarbon dating. These results suggest that chronometric efforts for the Zagros region might do best to focus on dating other organic remains, such as charcoal, using rigorous pre-treatment methods that sufficiently decontaminate Paleolithic-aged material. Our results provide a starting point for further work in developing high precision data for understanding the Middle to Upper Paleolithic transition in this region.

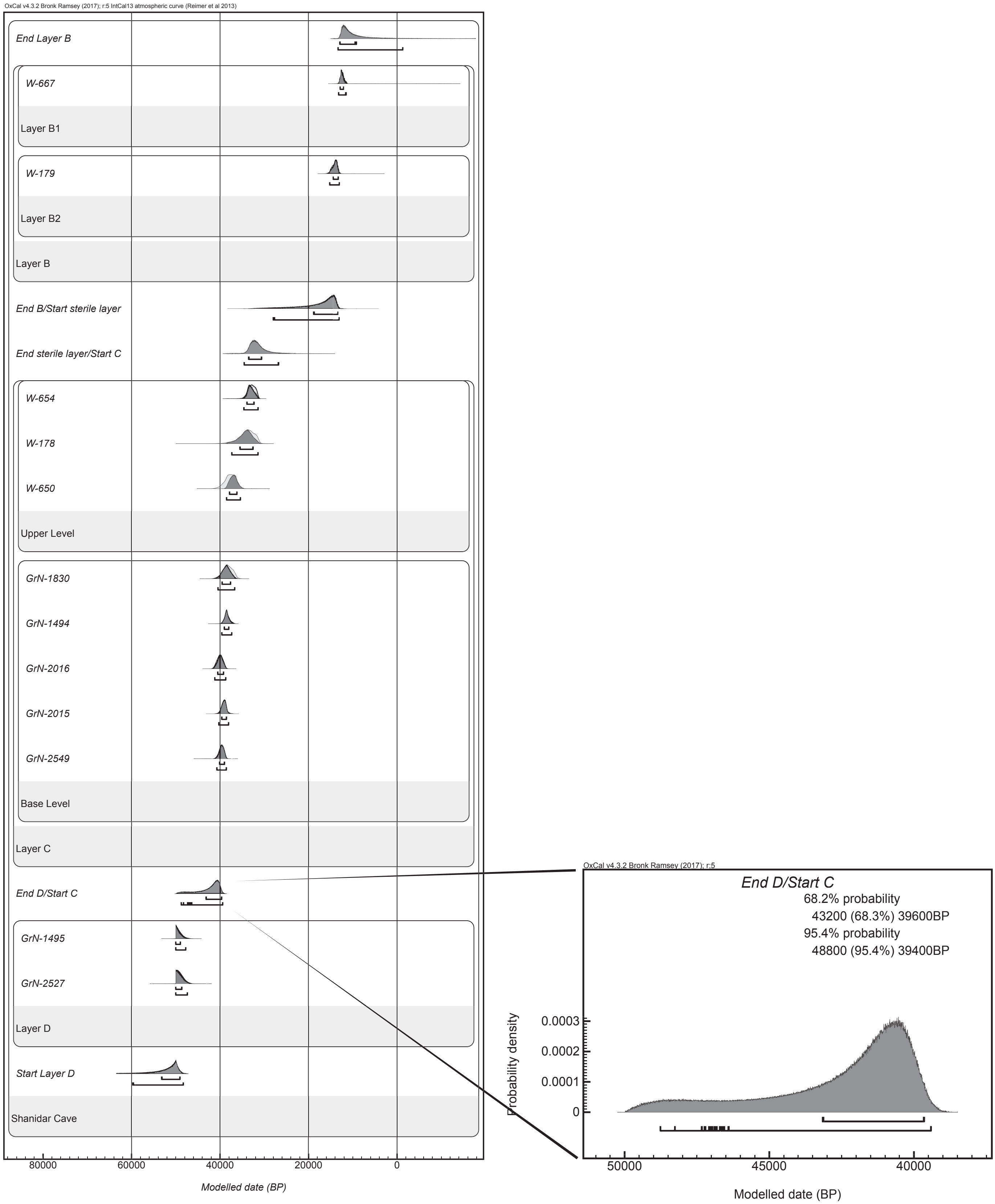

Figure 8. Bayesian model of radiocarbon dates for the Paleolithic sequence at Shanidar Cave, including those published by Hole and Flannery (1968), and Solecki (1963). This model has three separate phases corresponding to Layers D, C, and B. The boundary for the end of Layer D/start of Layer C corresponds to the Middle to Upper Paleolithic transition at the site. OxCal CQL code is shown in the SOM.

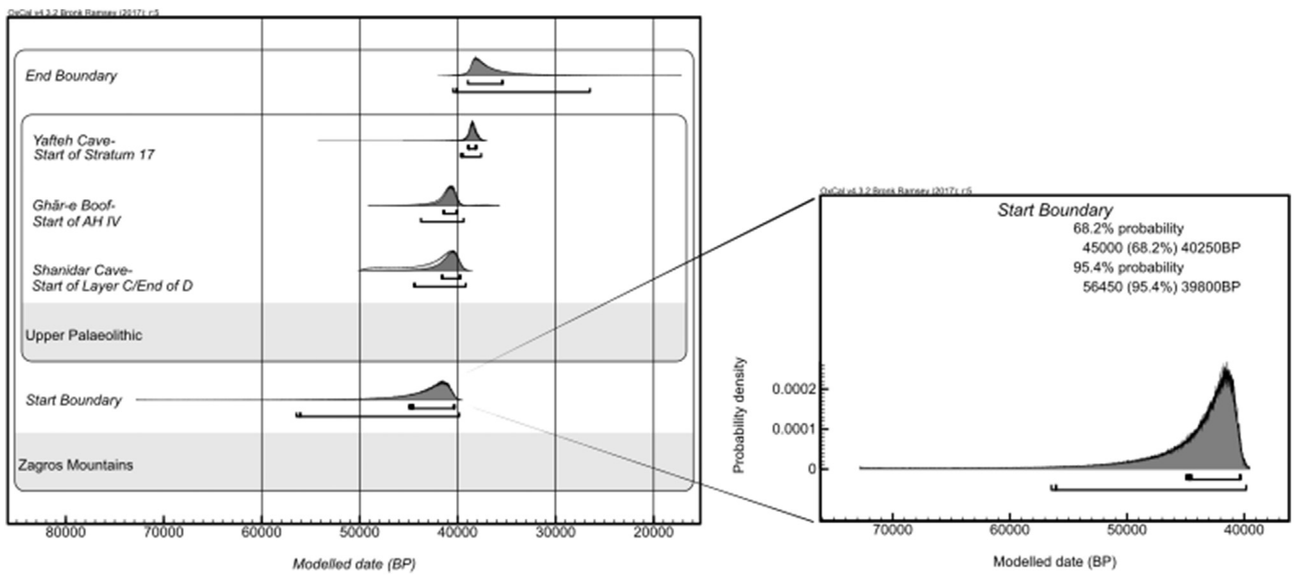

Figure 9. Bayesian model for the onset of the Upper Paleolithic in the Zagros Mountains, using modelled chronometric data for Yafteh Cave, Ghār-e Boof, and Shanidar Cave.

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Supplementary Online Material

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3-4g: Article under review

Ethel Allué, Ph.D; Isabel Expósito; Laxmi Tumung;Andreu Ollé; Behrouz Bazgir. Early evidence of Prunus and Prunus cf. amygdalus from Palaeolithic sites in the Khorramabad Valley, Western Iran. Under review in the journal of Comptes Rendus Palevol.

This article deals with the identification of the recovered charcoal samples from Gilvaran and Kaldar cave that allow the identification of Prunus spp and a preliminary reconstruction of the paleoenvironment of the region.

Elsevier Editorial System(tm) for Comptes rendus Palevol
Manuscript Draft

Manuscript Number:

Title: Early evidence of Prunus and Prunus cf. amygdalus from Palaeolithic sites in the Khorramabad Valley, Western Iran. Evidences anciennes de Prunus et Prunus cf. amygdalus des sites paléolithiques dans la vallée de Khorramabad, dans l'ouest de l'Iran.

Article Type: Full Length Article / Article original

Keywords: anthracology; Iran; Prunus spp.; palaeoecology; arboreal vegetation; fuel

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Abstract: Along with the early age obtained for the cultural remains attributed to anatomically modern humans from Kaldar Cave, the archaeological assemblages recovered from both Kaldar and Gilvaran Cave, located in the Khorramabad Valley (Iran), have yielded charcoal remains that allow the identification of Prunus spp. These remains correspond to the Middle and Upper Palaeolithic, which are the earliest finds attesting to the presence of this taxa in the area. Our anatomical observation of the samples revealed the presence of Prunus spp. (plums) and Prunus cf. amygdalus (cf. almond). This also reflects specific plant communities in the area, characteristic of open forest growing in cool, dry conditions. These results provide new insights into the Late Glacial arboreal cover in this area. Furthermore, anthracological evidence together with other contextual materials provides a great opportunity to assess how Neanderthals and early modern humans adapted to their surroundings landscape, and their relationship with their environment in this region and beyond.

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Opposed Reviewers:

Early evidence of *Prunus* and *Prunus* cf. *amygdalus* from Palaeolithic sites in the Khorramabad Valley, Western Iran.

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Abstract. Along with the early age obtained for the cultural remains attributed to anatomically modern humans from Kaldar Cave, the archaeological assemblages recovered from both Kaldar and Gilvaran Cave, located in the Khorramabad Valley (Iran), have yielded charcoal remains that allow the identification of *Prunus* spp. These remains correspond to the Middle and Upper Palaeolithic, which are the earliest finds attesting to the presence of this taxa in the area. Our anatomical observation of the samples revealed the presence of *Prunus* spp. (plums) and *Prunus* cf. *amygdalus* (cf. almond). This also reflects specific plant communities in the area, characteristic of open forest growing in cool, dry conditions. These results provide new insights into the Late Glacial arboreal cover in this area. Furthermore, anthracological evidence together with other contextual materials provides a great opportunity to assess how Neanderthals and early modern humans adapted to their surroundings landscape, and their relationship with their environment in this region and beyond.

Keywords: anthracology; Iran; *Prunus* spp. ; palaeoecology ; arboreal vegetation ; fuel

Evidences anciennes de *Prunus* et *Prunus* cf. *amygdalus* des sites paléolithiques dans la vallée de Khorramabad, dans l'ouest de l'Iran.

Resumé. Avec l'âge précoce obtenu pour les restes culturels attribués aux humains anatomiquement modernes de la grotte de Kaldar, les assemblages archéologiques récupérés à la fois de Kaldar et Gilvaran Cave, situés dans la vallée de Khorramabad

(Iran), ont donné des restes de charbon qui permettent l'identification de Prunus spp. Ces restes correspondent au Paléolithique moyen et supérieur, qui sont les premières découvertes attestant de la présence de ces taxons dans la région. Notre observation anatomique des échantillons a révélé la présence de *Prunus* spp. (prunes) et *Prunus* cf. *amygdalus* (voir l'amande). Cela reflète également des communautés végétales spécifiques dans la région, caractéristiques de la croissance des forêts ouvertes dans des conditions fraîches et sèches. Ces résultats fournissent de nouvelles idées sur la couverture arborescente Late Glacial dans cette zone. En outre, les résultats anthracologiques et d'autres matériaux contextuels offrent une excellente occasion d'évaluer comment les Néandertaliens et les premiers humains modernes se sont adaptés à leur environnement et leurs relations avec leur environnement dans cette région et au-delà.

Mots clefs : anthracologie, Iran, *Prunus* spp., paléoécologie, végétation arborée, combustible

1. Introduction

The genus *Prunus* includes a large number of species that are distributed throughout the northern hemisphere (Kurtto, 2009). This genus is part of the Rosaceae family and the Amygdaloideae subfamily. *Prunus* spp. is referred to several synonyms including *Prunus*, *Amygdalus* and *Cerasus*. In this work, to avoid confusion between the different accepted nomenclatures, we use *Prunus* spp., which includes all three mentioned genus names accepted in the Flora europaea (Kurtto, 2009). *Prunus* spp. is an entomophilous flowering tree or shrub with edible fruit (e.g. plums) or edible seeds (e.g. almonds). This genus includes 200 species of plums, almonds, peaches, apricots and cherries. Iran is the centre of origin of some of these species and a global centre of world production (Gharaghani, 2017; Vafadar et al., 2010). Iran's geographical characteristics allow these species to spread in various tree communities under semi-arid conditions, such as Pistachio-almond communities, edges of the oak forests, open steppe forests, and steppe-like communities (Heshmati, 2007; Kashki and Amirabadizadeh, 2011; Pourmoghadam et al., 2013).

Past evidence of *Prunus* includes palaeobotanical records which involve pollen, travertine imprints, charcoal, and seeds. Palynological records only permit identification to family level, i.e. Rosaceae, and pollen is usually absent or underrepresented due to the entomophilous character of this family (Djamali et al., 2008). According to Vafadar et al., (2010) *Amygdalus* L. (syn. *Prunus*) pollen grains from Iranian species are tricolporate and symmetric isopolar monads with a predominantly striated exine. According to these authors, the shape of the pollen grains allows different subgenera to be distinguished, whereas other features such as the exine show no differences. However, when the pollen is preserved in the archaeological record, it can only be identified as cf. *Prunus* (cf. *Amygdalus*) (Djamali et al., 2008; Vafadar et al., 2010). In Iran, there are several palynological sequences providing palaeoecological evidence from the Upper Pleistocene to the Holocene (Bottema, 1986; Djamali, 2008, 2009a, 2009b, 2012; El-Moslimany, 1987; Miller et al., 2013; Van Zeist, 1967). These sequences have yielded information on the arboreal cover in which Rosaceae is rarely present. Travertine imprints have preserved evidence of *Prunus*, but there have been very few records identified in natural environments (Ollivier et al., 2010). Charcoal and seeds in archaeological contexts are the most abundant evidence of this genus. *Prunus* stones from several species have been identified from the Upper Palaeolithic, usually burnt and related to wild fruit gathering (Martinoli et al., 2004; Zohary and Hopf, 1993). There are 26 species of almond that include two eco-geographical races: one is adapted to Mediterranean environments and the other occupies steppe forests or steppe-like environments (Zohary and Hopf. 2003). Archaeological evidence of this plant has been identified in Mesolithic and Neolithic layers in the Levant (Martinoli, 2004; Zohary and Hopf, 1993). The earliest evidence from Iran is from the Late Neolithic Tepe Musyan (Zohary and Hopf, 1993). Plums and cherries grow in temperate parts of Europe and Turkey, in woods and on cleared hills, and have been identified from the Neolithic. Some differences in the stones allow certain species to be distinguished, such as *Prunus spinosa*, and some types of almond have been recorded from Upper Palaeolithic deposits (Allué et al., 2010; Mason and Hather 2002; Martinoli, 2004).

Until now charcoal macro-remains have provided the largest dataset of *Prunus* evidence, most of this from archaeological sites in various contexts. As charcoal is related to the use of wood for combustion, most records are from the Upper Pleistocene to Holocene, whereas earlier evidence, where there is scarce evidence of fire, is rare.

Charcoal analysis (or anthracology) is based on the taxonomic identification of charred wood remains recovered from archaeological sites. Anthracology is aimed at recognising past vegetation and its evolution through time, as well as understanding human behaviour in relation to the use of vegetal resources, particularly as fuel (Chabal et al., 1999). The significance of charcoal analysis as a tool for palaeoecological reconstruction has been demonstrated and its interpretation is based on the ecological characterisation of the species depending on the climatic conditions and their diachronic evolution. Also charcoal remains from domestic fires allow us to understand the uses of wood as a raw material for fuel, manufacturing objects, and as a building material (Chabal et al., 1999).

In the Near East, studies of archaeobotanical remains (fruits, seeds and charcoal) have been focused on tracking evidence of early agriculture, yielding excellent evidence for the study of past vegetation and plant uses (e.g. Asouti, 2003; Asouti et al., CA; Asouti, 2013; Asouti and Kabukcu, 2014; Mashkour and Tengberg, 2013; Miller, 1985, 2003; Miller et al., 2011; Miller and Marston, 2012; Zohary and Hopf, 1993; Willcox, 1999, 2002; Emery-Barbier, and Thiébault, 2005). In Iran, these studies mainly focus on seeds and charcoal remains from Neolithic and Bronze Age archaeological sites (Mashkour and Tengberg, 2013; Miller, 1985, 2003; Miller et al., 2011; Rielh et al., 2012; Tengberg, 2012; Willcox, 1990). In contrast, Palaeolithic records within the country are very scarce, with the exception of the Middle Palaeolithic site of Qaleh Bozi in central Iran, where charcoal analysis was carried out (Biglari et al., 2009). Preservation problems and lack of adequate sampling and excavation could be the main reason for the absence of charcoal remains from Iranian Palaeolithic sites.

The aim of this work is to report the evidence of *Prunus* and *Prunus* cf. *amygdalus* yielded from Gilvaran and Kaldar caves. This evidence allows us to discuss palaeoenvironmental issues with regard to the presence of arboreal cover in the area during periods in which the region was occupied by culturally different human populations. These results are particularly important due to the scarcity of data from this period in the area, more specifically for providing new valuable evidence for the study of the Iranian Palaeolithic.

2. Site description

As a goal-oriented study with a regional and wide-ranging perspective, the Khorramabad research programme began in 2009. After a comprehensive field survey, in 2011-12 we carried out an extensive excavation programme at four Palaeolithic localities including Gilvaran, Kaldar and Ghamari caves and Gar Arjeneh rock-shelter (Fig. 1).

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Gilvaran Cave

Gilvaran Cave is situated in the northwestern part of the Khorramabad valley and located at 48 °: 18 ': 56 " E longitude, 32°: 28': 12 " N latitude, at about 1,225 m a.s.l. (Fig. 1). Excavation in Gilvaran involved two 2 x 2 m trenches, one near the cave dripline (trench A8) and the other about 20 m outside the cave entrance. Test pit AY1 exposed 4.8 m section of sedimentary deposit and is characterised by 5 main levels (Fig. 2). Level 1 consists of ashy blackish-green sediment with angular stones. It varies in thickness from 5 to 20 cm. This is the most recent level and contains an assemblage of Islamic materials. Level 2 consists of fine, light grey sediment with few angular stones. It varies in thickness from 28 to 84 cm and includes a Historical and Bronze Age record. Level 3 consists of grey, coarse sandy sediment that varies from 60 to 110 cm in thickness and which contains mixed evidence of Chalcolithic and Neolithic potsherds and lithic industries. Level 4 varies in thickness from 39 to 62 cm and consists of dark grey sediment with a large number of limestone blocks of different sizes. It contains an Upper Palaeolithic assemblage. Level 5 is a reddish brown deposit with many large limestone blocks. It increases in depth from the northern section towards the south, varying from 2.45 to 2.85 m in thickness. It includes two sub-levels that do not vary in colour. Evidence of Middle Palaeolithic industry is found in level 5, with mixed Middle and early Upper Palaeolithic/Baradostian industries in its sub-level 2 (Bazgir, 2013; Bazgir et al., 2014).

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Kaldar Cave

Kaldar Cave is situated in the northern Khorramabad Valley at 48° 17′ 35″ E longitude, 33° 33′ 25″ N latitude, and an elevation of 1,290 m a.s.l. It is 16 m long, 17 m wide, and 7 m high (Fig. 1). Its great potential was realised during our 2011-12 test excavation. During the 2014-15 excavation season at Kaldar, we enlarged the excavation area, focusing on gaining a better understanding of the stratigraphy and obtaining samples for dating. We dug a 3 × 3 m trench near the entrance and kept a 50 cm bulk sample from the previous test pit (squares E5, E6, E7, F5, F6, F7, G5, G6 and G7) (Fig. 2). The excavation was conducted using 5 cm spits within each archaeostratigraphic unit, as well as 3D recordings of all findings. The excavated trench exposed an approximately 2 m (195 cm) section of sedimentary deposit, which is characterised by five main layers. Layers 1 to 3 (including sub-layers 4 and 4II) consist of blackish-green ashy sediment containing both thick and thin angular limestone clasts. These layers vary in thickness from 60 to 90 cm and contain many phases dated as Holocene, i.e. the Islamic and Historical eras, Iron Age, Bronze Age, Chalcolithic, and Neolithic. However, due to the presence of some bioturbation in these layers, the phases were recognised only by a preliminary study of the potsherds, metal artefacts, and some diagnostic lithic artefacts from the lower layers. Layer 4 (including sub-layers 5, 5II, 6 and 6II) consists of a silty but compact dark-brown sediment with cultural remains from the Upper and Early Upper Palaeolithic. In the uppermost parts of this layer, two fireplaces made of clay were recovered and dated through thermoluminescence as 23,100 ± 3,300 BP and 29,400 ± 2,300 BP (Bagzir et al., 2017; Becerra-Valdivia et al., 2017). The dates obtained show that these fireplaces were made or re-used from existing older sediment from the upper part of this layer in the later stages of the Upper Palaeolithic. AMS radiocarbon dates of 38,650–36,750 cal BP, 44,200–42,350 cal BP, and 54,400–46,050 cal BP have been obtained from charcoal material located below this layer (Bazgir et al., 2017). Layer 5 (including sub-layers 7 and 7II) consists of an extremely well-cemented, reddish-brown sediment with some small angular limestone blocks and Middle Palaeolithic artefacts (Fig. 2). To date, no radiometric data is available for this layer (Bazgir et al., 2017).

3. Materials and Methods

The charcoal study is based on materials recovered from the 2011-14 field seasons at Gilvaran, Kaldar and Ghamari Caves and Gar Arjene rock-shelter (Bazgir, 2013; Bazgir et al., 2014). After sieving the sediments and hand sampling, only Gilvaran and Kaldar caves yielded samples for this study (Fig. 2). All the sediments were water sieved on the spot, except those of Ghamari Cave where, due to the high elevation difficulties, the sediments were dry sieved. The samples from other localities were very small and were not well preserved enough for further analysis. At Gilvaran Cave, charcoals were recovered from levels 3 and 4, yielding positive results. The charcoal samples recovered from level 4 are attributed to the Upper Palaeolithic, showing a clear association with other archaeological material (lithic remains and bones). The remains from Kaldar cave came from two layers, Layer 4 belonging to the Upper Palaeolithic and Layer 5 belonging to the Middle Palaeolithic (Bazgir et al., 2017).

For charcoal identification, the remains were fragmented by hand in order to obtain the three wood anatomy sections. This permitted a description of the cell structure. The charcoal fragments were observed using a metallographic reflected light microscope with dark and light fields, at x50, x100, x200, and x500 magnifications (Olympus BX41). The identification was supported with various wood anatomy atlases (Fahn et al., 1986; Parsapajouh et al., 1987; Schweingruber and Landlot, 2005). Charcoal analysis does not always permit a species-level identification due to factors such as size of the charcoal piece, anatomy defects produced by combustion or post-depositional processes, low degree of anatomical variability among species, or the absence within the fragment of all the characteristics needed to define a species. The identification categories used in charcoal analysis are genus, family, type, and occasionally species. Quantification of charcoal assemblages is usually based on the number of fragments or the presence/absence of the different taxa. Furthermore, depending on the number of fragments a statistical approach can be taken. Usually a minimum number of fragments should be studied in order to obtain a valid data set. A commonly agreed-upon and widely accepted standard among authors is that between 250 and 500 fragments per level are required to validate a sample (Chabal et al., 1999). At Gilvaran and Kaldar caves the number of remains is small; we will, therefore, take into account the presence of taxa to explain our results.

The pollen results set out below come from a preliminary study of sedimentary samples from Gilvaran and Kaldar caves. The results are extremely poor, however, especially in the case of Kaldar cave, we consider it appropriate to refer to the taxonomic variability identified, which contributes to endorsing the palaeoenvironmental reconstruction generated from the results of the anthacological analysis.

4. Results

Gilvaran cave Level 4 (Upper Palaeolithic) yielded 30 charcoal fragments belonging to *Prunus* sp. Kaldar cave yielded 30 charcoal fragments from two archaeological layers. Layer 5 yielded 17 fragments including *Prunus, Prunus* cf. *amygdalus, Salix* and a few undetermined fragments. The Middle Palaeolithic Layer 4 yielded 13 fragments showing the presence of *Prunus* and *Prunus* cf. *amygdalus*, as well as a few undetermined fragments (Table 1).

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Prunus is the only recurring taxa in the results from the 60 remains from Kaldar and Gilvaran caves. This genus includes different subgenera among which *Prunus* (e.g. *P. divaricata*, *P. spinosa*), *Amygdalus* (e.g. *A. fenzliana*, *A. communis, A. scoparia*), and *Cerasus* (e.g. *C. incana*, *C. mahaleb*) are the most common species. in Iran. *Prunus* wood anatomy commonly shows a diffuse to semi-ring distribution of the pores in the transversal wood section (Schweingruber and Landlot, 2005). *Amygdalus* show a ring-porous distribution of vessels, whereas the wood of other types, such as *Cerasus* and *P. spinosa,* has diffuse porosity. Ray cells are uni-seriate to 3- and 7-seriate depending on the species. Vessels show spiral thickenings with simple perforation plates. Three different types of *Prunus* can be regrouped according to the wood anatomy (Allué, 2016; Heinz and Barbaza, 1998; Ntinou, 2002). *Prunus* type 1 rays does not have more than 2 cells; *Prunus* type 2 contain between 3 and 4 cells per ray; and *Prunus* type 3 has more than 5 cells. Each type corresponds to different groups, for example type 1 includes *Prunus avium/padus* (cherry/European bird cherry), type 2 is *Prunus spinosa/mahaleb* (blackthorn/mahaleb cherry), and type 3 is *Prunus spinosa/amygdalus* (blackthorn/almond tree). Ntinou (2002) also uses three groupings according to the species currently present in Greece. Group I includes *P. armeriaca*, *P. dulcis*, *P. persica* and *P. webbii*. When the rays were 7- or 8-seriated with ring-porous wood they were identified as *Prunus* cf. *amygdalus*. Group II with diffuse-porous wood and 2 to 7 cell rays (an average of 5) includes *P. domestica*, *P. padus*, *P. mahaleb*, *P. spinosa* and *P. cerasifera*. Group III with semi ring-porous wood to diffuse-porous wood and with 2 to 4 ray cells includes *P. avium* and *P. cerasus*.

The samples from Gilvaran are woods with a diffuse porosity distribution; 5 to 7 cells in rays, ruling out a possible identification as *Amygdalus* type. In contrast, some of the samples from Kaldar cave have the anatomical characters of *P.* cf. *amygdalus,* showing ring porous wood (Fig. 3).

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5. Discussion

The study of the charcoal remains from Kaldar and Gilvaran caves shows the presence of *Prunus* and *Prunus* cf. *amygdalus* during the Middle and Upper Palaeolithic. This evidence, together with other palaeoenvironmental proxies at Kaldar cave, suggests temperate “interglacial” environmental conditions (Bazgir et al., 2017). The presence of *Salix* in both the anthracological and palynological record indicates that there were active water sources or flows, and steppe-like or open forests areas in which *Prunus* ssp. could grow. Other data records from Kaldar cave show the presence of herpetofauna, as well as macro and micromammals, suggesting open wooded areas and dry steppe areas indicating mild conditions. The poor palynological record from here shows, however, the presence of temperate taxa as *Corylus* or evergreen *Quercus*. According to the archaeological and palaeoenvironmental data, humans, animals and plants were well adapted to these conditions and the area acted as a refugee (Bazgir et al., 2017).

Species belonging to the genus *Prunus* are distributed among different plant communities in the Iranian region. They form the undergrowth of oak forests, the Pistachio-almond steppe, or stands in open areas (Heshmati, 2007). The Pistachio-almond steppe is present throughout the area and is characterised by dominance of *Pistacia* and *Amygdalus cf. scoparia*. This type of vegetation has been interpreted at the Qaleh Bozi Palaeolithic site as well, where two taxa were identified, *Salix/Populus* and

Pistacia, underlining the presence of open steppe-forests and riverside formations (Biglari et al., 2009). Evidence from the early Holocene/early Neolithic suggests that Pistachio-almond vegetation was spread throughout Iran, Turkey and other neighbouring regions (Asouti, 2003; Miller, 2011). The evidence obtained from Gilvaran and Kaldar caves shows the presence of two different taxa: *Prunus* cf. *amygdalus* and *Prunus* ssp. These indicate that there was arboreal cover in the area and their remains are probably related to the use of wood as fuel.

Evidence of *Prunus* in an archaeological context has been identified at a number of sites showing significant values during the Late Glacial (Allué et al., 2012a; 2010; Bazile-Robert 1980; Henry et al., 2013) (Fig. 4, Table 2). In earlier periods, the *Prunus* ssp. communities were probably more important than assumed. The Azokh cave layer II charcoal record, dated to ca. 100 ka, shows high values (80%) of *Prunus*, mostly *P. spinosa*, and *P. mahaleb types*, (Allué et al., 2016) is interpreted as a pioneer vegetation succession or pre-forest formation in an open woodland. Several sites in Greece show the presence of *Prunus* (*Prunus* type *spinosa* group and *Prunus* cf. *amydalus*) and there were particularly high numbers of remains in Theopetra cave from MIS 6 to MIS 3 (Ntinou and Kyparissi-Apostolika, 2016). The *Prunus* identified in that sequence belonged to the *P. spinosa*, *P. mahaleb* and *P. prostrata* types and the authors relate the dominance of *Prunus* and *Juniperus* to unstable climatic conditions in an open steppe-like environment (Ntinou and Kyparissi-Apostolika, 2016). In both sequences at Azokh and Theopetra, *Prunus* is interpreted as part of the pioneer vegetation in the glacial and interglacial vegetation cycles (Allué, 2016; Ntinou and Kyparissi-Apostolika, 2016).

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Throughout MIS 3 and MIS 2, several western European records from Iberia, SE France, Italy and Greece show evidence of *Prunus* (Allué et al., 2007; 2012a; 2012b; 2017; Bazile-Robert, 1980; Fiorentino and Parra, 2015; Maspero, 2004; Ros, 1987; Ntinou, 2002, 2010, 2016). According to these charcoal studies, *Prunus* was present throughout MIS 3 and MIS 2 in Western Europe, but montane pine forests were the dominant arboreal cover. *Prunus* was increasingly represented in the woodlands in the

Late Glacial and in general at the beginning of the Holocene, related to climatic improvement (Allué et al., 2012a, 2012b) (Fig. 4). Its increase is usually related to the development of pre-forest communities growing under milder climatic conditions. The good adaptation of the different *Prunus* species enabled them to resist cold and dry conditions, and they were pioneer plants during the Pleistocene glacial and interglacial cycles overall from Greece to Western Asia. There was an important spread of this taxa during the Late Glacial and its archaeological remains are related to its use as fuel as well as fruit gathering as food (Allué et al., 2012a; Filipovic et al., 2010; Heinz et Barbaza, 1998; Henry et al., 2013). The presence of *Prunus* in the eastern Mediterranean and western Asia (Central Asia) might be also related to the development of open forests more adapted to cold and dry climates, lacking montane pine components. This fact might be linked to specific biogeographical and environmental conditions in these different areas since the Pliocene, as part of the disjointed distribution of species between the different areas (Ribera and Blasco-Zumeta 1998).

As mentioned earlier, the absence of *Prunus* in palynological sequences due to its entomophilous dispersal means it is difficult to obtain comparable records from continuous natural deposits. Palynological deposits from Iran show that during the last Pleniglacial and Late Glacial the dominant vegetation was characterised by steppe-forest with predominant herbaceous components including *Artemisia* and Chenopodiaceae (syn. Amaranthaceae) (Djamali et al., 2012). This vegetation is typical of open, dry steppe landscape with little arboreal cover. *Hippophae rhamnoides* spread throughout MIS 3, being the most significant arboreal cover along with riverside species. The palynological record from Kaldar, although very poor, suggests, however, that in these environments with mesic, thermophilous and riparian taxa, *Prunus* was also present. Furthermore, according to Rajei et al. (2013) the presence of *Gnofarmia*, a species of insect, during the Late Glacial Maximum indicates the presence of the host plants: *Prunus scoparia* and *Prunus felziliana.* Rajei et al. (2013) also suggest that the presence of these host plants could indicate that the area acted as a refuge during cold periods. Based on the data from Gilvaran and Kaldar caves, the presence of *Prunus* could be tracked to earlier periods and confirm the presence of these taxa during the Pleistocene. The precise dating at Kaldar cave was carried out using *Prunus* and *Prunus* cf. *amygdalus* fragments, demonstrating their presence in MIS 3.

During MIS 3 and, more precisely, the period in which these caves were occupied, the Zagros Mountains were characterised by climatic fluctuations of temperate-humid and cold-dry phases. The most complete palynological sequence from Lake Urmia indicates that in the north-western part of Iran, the last glacial landscape was dominated by *Artemisa*, Chenopodiaceae (syn. Amaranthaceae), and other steppe grasses. There was more arboreal cover than in previous periods and this was characterised by higher numbers of *Hippophae rhamnoides* (Djamali et al., 2008). According to these authors, winter temperatures were lower than today and there was very little arboreal cover (Djamali et al., 2008; van Zeist 1965). Data obtained from the Damavand volcano (northern Iran) also suggests steppe-like vegetation in the Late Glacial; however, the increase of tree taxa in several samples suggests the occurrence of some wetter periods (Sharma et al., 2014). The presence of at least two species from the genus *Prunus* and the presence of *Salix* in Kaldar and Gilvaran caves suggest that there was arboreal tree cover during the interglacial periods in the Late Glacial. Additionally, the palaeoecological evidence from palynological record, including the presence of *Corylus*, evergreen *Quercus*, *Salix* and Cyperaceae, among other taxa, and from micro- and macromammals from Kaldar cave, supports this interpretation of interglacial conditions.

Keeping in mind how early the modern human occupation at Kaldar Cave was, and adding the charcoal evidence to the other cultural remains recovered from this locality, we are able to assess an important climatic moment that provides a great deal of information for reconstructing the relationship between the environment and human occupation in this region and beyond. The dates obtained from the lower part of the Upper Palaeolithic sequence at Kaldar Cave are among the oldest attributed to a lithic industry produced by anatomically modern humans (AMHs) in western Asia. From an archaeological and anthropological point of view, the timing of modern human emergence and demise of the Neanderthals has been always a pivotal issue. Moreover, data on the climatic conditions during this crucial moment provides important information on the role of humans and their relationship with the surrounding environment. Therefore, enlarging the datasets, along with the high potential of the Palaeolithic deposits in the region, would certainly provide a great opportunity to better understand human occupation and adaptation in this region and beyond.

6. Conclusions

The identification of charcoal remains of *Prunus* from Kaldar and Gilvaran caves shows that these trees and shrubs were probably important in the environment even during climatically cold periods. The wooded vegetation was probably characteristic of open steppe. These results and the results obtained using other proxies from the sites excavated in the Khorramabad Valley, allow us to identify this area as a refuge for which humans were probably well adapted ,where resources were available. Charcoal evidence from Palaeolithic sites is generally scarce; hence, new evidence is always important to enlarge the datasets for the study of past vegetation and plant use. Therein lies the importance of the well dated (Kaldar cave) – key archaeological site- in the region where there are large number of caves and rock shelters that could strength these datasets for understanding more about Neanderthals and early modern human occupation in respect to their adaptation with climatic condition from further studies.

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Figure Captions

Figure 1. Map of the area showing the location of the sites. The geographic position of the Khorramabad Valley and the position of the localities excavated in 2011-12 field season indicated on an aerial photograph.

Figure 2. [left] stratigraphic profile of Gilvaran cave. [right] Stratigraphy (eastern section) of Kaldar with location and results of the dated samples. Created by A. Ollé and B. Bazgir. Modified from Bazgir et al., 2017.

Figure 3. B) Transversal section of *Prunus* cf. *amygdalus* from Kaldar showing a ring-porous Distribution; B) Tangential section of *Prunus* sp. showing 2 to 3 seriated ray cells.

Figure 4. Distribution of sites and areas mentioned in the discussion refering to *Prunus* anthracological evidences. 1) Balma del Gai; 2) Molí del Salt; 3) Arbreda; 4) Salpetriere; 5) Coudoulous II; 6) Grotta delle Mura; 7) Grotta S. Maria D'Agnano; 8) Grotta Paglicci; 9) Konispol; 10) Klissoura; 11) Lakonis; 12) Theropestra cave; 13) Manot Cave; 14) Azokh cave.

Figure 1
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Figure 2

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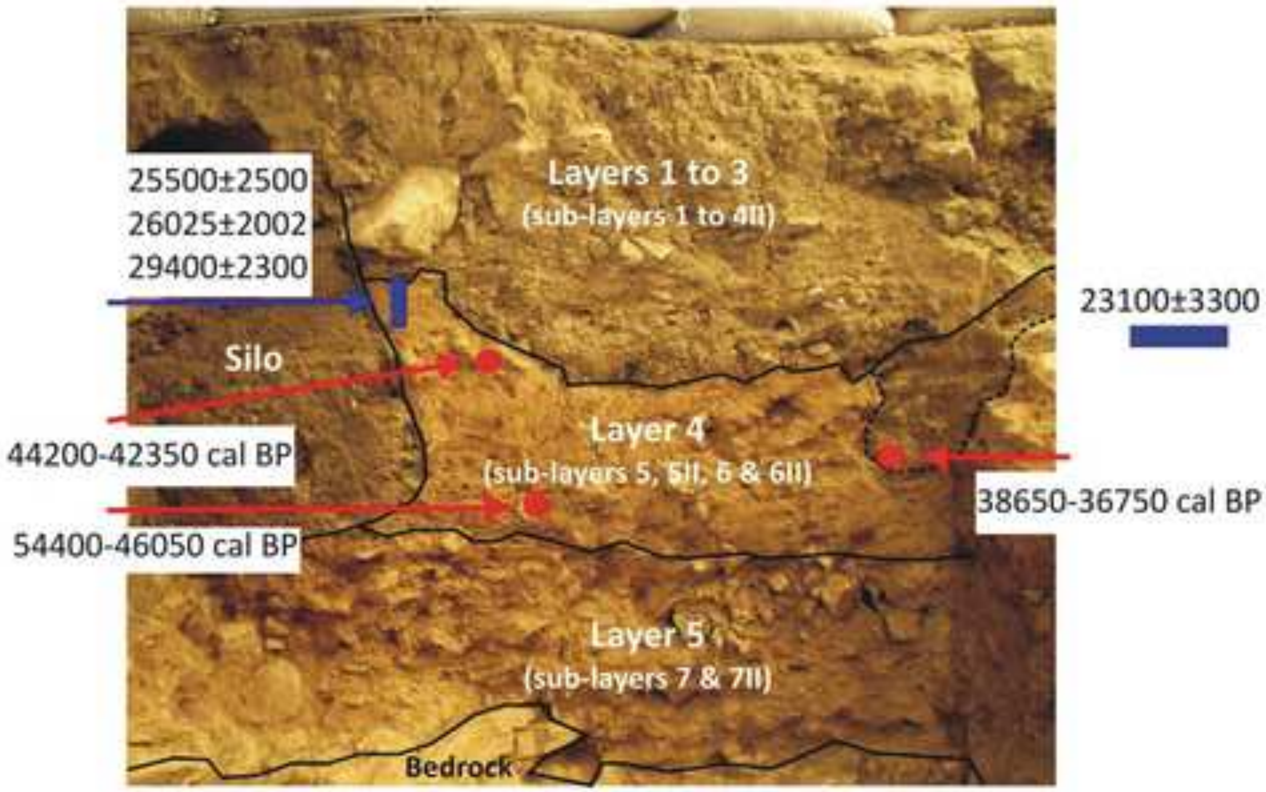

Figure 3

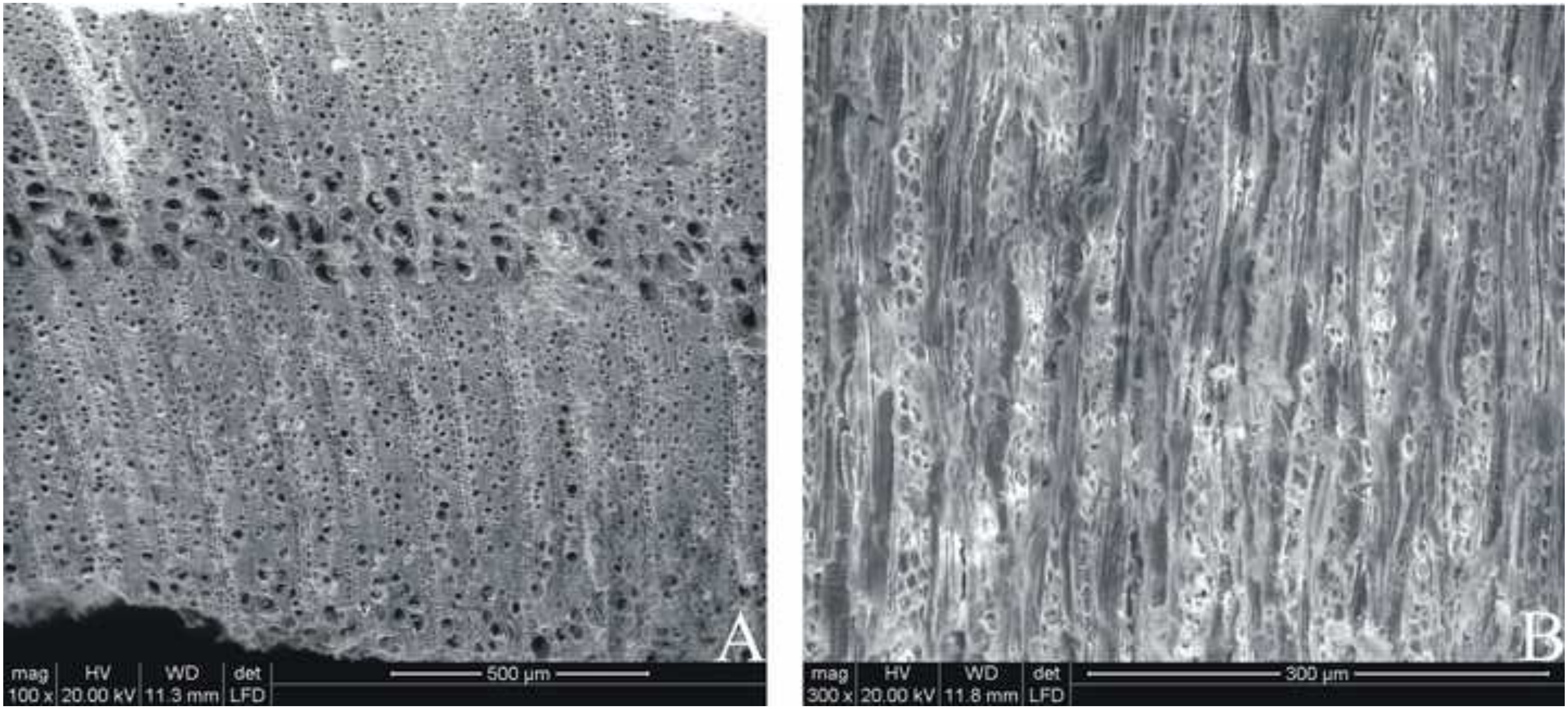
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Figure 4

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Table / Tableau 1

	Kaldar		Gilvaran
Taxa	**Layer 4**	**Layer 5**	**Layer 4**
Prunus	2	5	30
Prunus cf. *amygdalus*	5	1	
cf. *Prunus*		2	
Salix		2	
angiosperm	3	2	
undetermined	2	8	
Total	**13**	**17**	**30**

Table 1. Results of the anthracological analyses from Kaldar and Gilvaran caves

Table / Tableau 2

MIS	Chronoculture	Name of the site	Location	Layer	Taxa	Values	Reference
MIS 2	Upper Paleolithic	Konispol	Albania	42-36	*Prunus cf. amygdalus*	80-100%	Ntinou et al., 2016; Hansen, 2001
		Theropestra cave	Greece		*Prunus cf. spinosa*	0-10%	
		Grotta Paglicci	Italy		*Prunus cf. amygdalus*	20-40%	Maspero 2004
		Balma del Gai	Spain	I (140-150)	*Prunus*	10-30%	Allué, 2007
		Molí del Salt		Asup	*Prunus*	40-50%	Allué et al., 2010
				B1		10-30%	
				B2		10-30%	
		Salpetrière	France	107	*Prunus cf. amygdalus, Prunus*	<1%	Bazile-Robert, 1981
MIS 3	Early Upper Paleolithic	Klissoura	Greece	IV	*Prunus cf. amygdalus/Prunus cf. spinosa*	50%	Ntinou, 2010
		Manot Cave	Israel	areas A-G	*Prunus cf. amygdalus*	presence	Barzilai et al., 2016
		Grotta Paglicci	Italy		*Prunus cf. amygdalus*	30%	Maspero, 2004
		Grotta S. Maria D'Agnano			*Prunoideae*	10-30%	Fiorentino and Parra, 2015
		Grotta delle Mura			*Prunus cf. spinosa, cf.maheleb*	20-40%	
		Arbreda	Spain	H	*Prunus*	10-30%	Maroto, 1994
				I			
	Middle Paleolithic	Lakonis	Greece		*Prunus sp.*	presence	Ntinou et al., 2016 ; Panagopoulou, 2004)
		Theropestra cave			*Prunus cf. spinosa*	60%	
MIS 4	Lower Paleolithic	Azokh	Nagorno-Karabagh	II	*Prunus*	80%	Allué, 2016
MIS 5		Coudoulous II	France	7a1, 7a2	*Prunus spinosa*	3-14%	Théry-Parisot et al., 2008
		Theropestra cave	Greece		*Prunus cf. Spinosa*	0-5%	Ntinou et al., 2016
MIS 5e						10-50%	
MIS 6-5	Lower Paleolithic					50-70%	

Table 2. Synthetical table of Lower to Upper Pleistocene sites with *Prunus* remains

Chapter 4: Kaldar Cave Lithic Industry

4-1: Middle Paleolithic

The recovered lithic assemblages from both excavation seasons (2010-11&2014-15) from layer 5 at Kaldar Cave clearly show an outstanding Mousterian technology. The lithic artifacts are dominated by tools made by Levallois technique and show a high number of pointed and elongated tools mostly in the form of flakes and points. The retouched Mousterian points also consist a considerable percentage of the assemblage. Our technological analysis on the Middle Paleolithic lithic assemblage of Kaldar Cave shows a high density of pointed elements that might have been the main intention of tool making strategy between the makers of these tools at Kaldar Cave. Keeping this in mind, as an ongoing functional analysis, we are trying to reconstruct the function of these tools to confirm our hypothesis related to the hunting intentions. However, considering the high percentage of points and pointed pieces, not only within the Middle Paleolithic layer, but also in the Upper Paleolithic assemblage of Kaldar Cave, we carried out a detailed and precise metric analysis using clustering method to find out more the similarities and differences between this two industries. The mentioned analysis is prepared as an article that would be submitted to a journal for publication soon. The entire draft of the manuscript is presented at the end of this chapter (chapter 4).

4-2: Upper Paleolithic

The recovered Upper Paleolithic at Kaldar Cave with the achieved chronometric dates could be the outstanding part of this research project. Besides a clear laminar technology with several diagnostic technological elements that comes as the Baradostian or Zagros Aurignacian finger prints (for example: Arjeneh points, carinated pieces and different blade and bladelet cores), Kaldar Cave provides a unique blade and bladelet assemblage that might be considered as an index for the Baradostian assemblage within Iranian Zagros and beyond. Moreover, this assemblage is accompanied by a detailed chronometric dates that provides a great opportunity for a comparision analysis with other localities in the Khorramabad Valley and perhaps all the Paleolithic localities within Central Zagros.

In addition to the mentioned advantages, as a rare case, Kaldar assemblage also provided the chance to study the transition from Middle to Upper Paleolithic. In this regard, as an ongoing technological studies, for the timing, we analysed the entire points recovered from Layer 5 and 4. The below results are among an underway collaboration with our colleagues from Research Institute of Cultural Heritage and Tourism Organization of Iran (RICHT) which are in preparation process as an article to be submitted for publication. The aim to include these results in this thesis is just to show the potential of Kaldar Cave for the study of Middle to Upper Paleolithic transition.

Comparative Analysis on Lithic Manufacturing Technology Between Neanderthals vs Homo-Sapiens: A Case Study Using Clustering Method on Recovered Points from Layers 5 and 4 at Kaldar Cave (Khorramabad Valley; Western Iran)

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Abstract:

As a rare case in the Zagros Mountains, Kaldar Cave provides evidence for the existence of both Mousterian and Baradostian industries, along with geochronological data for its Upper Paleolithic layers ranging from 36000 to 54000 cal B.P, which are some of the earliest cultural evidences from Modern Humans out of Africa in western Asia. Therefore, it furnishes a unique opportunity to study and test the possible *in situ* transitional developments from one to the other. Our study is focused on extracting accurate and detailed information for analyzing wider range of elements and variabilities on several indexes within the tools. We used SPSS software for performing clustering method, attempt to build up an efficient comparative analysis in the differences and similarities between the Mousterian and Baradostian points recovered from Kaldar Cave. Results indicate a significant and meaningful differences within all the applied elements between the points in layers 4 and 5. In addition, our analysis also show that, right at the junction of the two layers (at the bottom of layer 4 and in the upper most part of layer 5) similar points exists. The differences might be interpreted as different behavioral patterns in manufacturing industries between Neanderthals and modern humns. Moreover, the similarities might show some clues on inheriting or *in situ* evolution of the Upper Palaeolithic from the local Mousterian.

Introduction

The age, place of origin, evolution of the transition from Middle to Upper Paleolithic and the timing of the modern humans movement into Europe, have been for a long time a central debate for the archaeologists and paleoanthropologists. The arguments continue and yet to be resolved due to new evidences coming out from different regions casting more complexities in the topic. Earlier, there was consensus among many researchers that the Levantine is the single origin for the dispersal of the modern humans into Europe. More specifically, in the southern Levant, they argued that technology of the modern projectiles developed in situ from the Middle Paleolithic (e.g., Bar-Yosef and Kuhn,1999; Copeland, 2003; Marks, 2003; Skrdla, 2003). However, later on, some noted that the so called Aurignacian may not have originated in only one area (see Groucutt et al. 2015, Douka et al. 2013). In addition, it has been suggested that the ages of the so-called “transitional” or Initial Upper Palaeolithic layers at Ksar Akil may represent that the transition from the Middle to Upper Palaeolithic in this area (and possibly in the wider northern Levant) occurred later than previously estimated. This finding would cast doubt on the assumed singular role of the region as an origin for human dispersal into Europe (Douka et al. 2013, see also Bazgir et al 2017). Taking into account the scarcity of excavated and well documented sites in the Zagros, which was mostly due to political instabilities in the area, remains of human fossils are scarce. Poor preservation of organic materials within the sites is another factor for this (Becerra-Valdivia et al. 2017). However, based on diagnostic lithic industry and recent dates from the Upper Paleolithic sequence of Kaldar Cave, the similar characteristics of the artifacts with those of European sites assume its importance as a key archaeological sites that could provide answer to some of the mentioned obstacles. In our techno-typological analysis on the Kaldar lithic assemblages, we observed a significant change from manufacturing flakes into blade and bladelet industry (Bazgir et al. 2017). The potential of the quantified results made us thinking on performing statistical analysis for analyzing wider range of elements and variabilities on several indexes within the tools. In this study we present results from a clustering analysis on the recovered points from Kaldar Cave and propose a possible in situ evolution of the Baradostian from the local Mousterian in the Zagros Mountains. However, more studies is needed to refine these results which implies study of more lithic assemblages in the region.

Material and method

The materials studied here, consists of 35 pieces of diagnostic Mousterian points from Layer 5 and 21 diagnostic Baradostian points from layer 4 of Kaldar Cave. All the analyzed pieces were selected for this study are the complete points without breakage or any other taphonomic or post depositional damage. In this study, the size and metric volume of each point was measured for comparison. Details of the measured elements are shown in Table 1. All the measurements represent in mm unit (Table 1).

				Layer 5		
	Tool number	Length	Width	Maximum thickness	Width at 1/5 of the length from the button	Thickness at 1/5 of the length from the tip
1	1021	34	21	8	19	5
2	1070	68	26	8	26	6
3	520	42	29	8	29	7
4	1094	29	16	3	15	2
5	1138	56	23	11	20	9
6	844	63	37	16	36	10
7	1106	49	21	5	20	5
8	1145	50	23	7	22	5
9	967	31	15	3	14	2
10	964	38	19	7	19	3
11	770	37	27	7	24	4
12	1797	33	25	9	25	6
13	986	56	20	12	16	11
14	913	57	28	10	26	10
15	952	55	26	8	26	7
16	1020	32	19	5	19	4
17	1126	62	26	10	23	10
18	1100	54	23	9	20	9
19	1101	61	19	10	19	6
20	1097	52	23	6	23	5
21	1002	45	21	8	21	6
22	1063	49	14	6	13	6
23	1073	42	19	8	16	6
24	1082	60	33	12	32	8
25	843	41	21	7	21	4
26	977	59	22	4	18	4

27	1283	33	23	9	19	6
28	1051	38	25	9	24	9
29	1033	37	26	6	26	5
30	1044	53	16	6	15	4
31	1048	48	20	12	20	8
32	958	50	34	10	33	7
33	1134	49	20	4	20	5
34	1106	37	15	7	7	4
35	994	47	25	6	24	4
				Layer 4		
	Tool number	Length	Width	Maximum thickness	Width at 1/5 of the length from the button	Thickness at 1/5 of the length from the tip
1	765	28	9	4	9	3
2	282	22	9	1	8	1
3	741	39	11	5	8	4
4	785	24	10	5	9	3
5	889	43	18	10	17	10
6	1257	43	14	5	14	3
7	806	53	24	7	14	18
8	900	29	6	3	6	2
9	1254	42	12	6	11	4
10	922	40	28	11	26	6
11	745	22	9	1	9	1
12	874	41	21	4	20	4
13	813	45	19	7	18	4
14	911	34	11	5	10	5
15	908	47	17	5	15	4
16	942	53	18	10	16	9
17	898	37	21	4	17	4
18	705	40	10	5	10	2
19	167	42	14	4	13	3
20	1	57	23	6	12	14
21	2	46	16	7	16	4

Table 1: Details of the measured elements (all represented in mm).

Taking into account that before doing any statistical analysis, assumption of normality and homogeneity of variance must be tested, therefore, the assumption of normality of the data on differences in variabilities of the length, width, maximum thickness and volume of the points from both the layers was tested (table 2).

One-Sample Kolmogorov-Smirnov Test

		Length	Width	Thickness	Calculated volume
N		56	56	56	56
Normal Parameters[a,b]	Mean	44.1786	20.0000	6.9821	9.4882
	Std. Deviation	10.92138	6.63873	2.94489	2.17235
Most Extreme Differences	Absolute	.061	.083	.105	.058
	Positive	.061	.058	.105	.058
	Negative	-.058	-.083	-.066	-.048
Kolmogorov-Smirnov Z		.458	.621	.784	.433
Asymp. Sig. (2-tailed)		.985	.835	.571	.992

a. Test distribution is Normal.

b. Calculated from data.

Table 2: Assumption of normality of the data on differences in variabilities of the length, width, maximum thickness and volume of the points from layers 5&4

Based on the non-parametric Kolmogorov–Smirnov test, the significant values that was displayed in red in Table 2, the error rate is only 0.05, therefore, the assumption of normality for the sizes of variables for processing further is established. Based on the results in Table 3, based on Levine's test, the homogeneity of variance is also exist. So we are allowed to use parametric tests (Independent T-test) to compare each piece between the two layers.

Group Statistics

	Layer	N	Mean	Std. Deviation	Std. Error Mean
Length	4	21	39.3810	9.92712	2.16627
	5	35	47.0571	10.59396	1.79071
Width	4	21	15.2381	5.94058	1.29634
	5	35	22.8571	5.30340	.89644
Thickness	4	21	5.4762	2.60037	.56745
	5	35	7.8857	2.79465	.47238
Calculated volume	4	21	8.5176	1.99893	.43620
	5	35	10.0705	2.08629	.35265

Table 3: Levine's test indicating the existence of homogeneity of variance

In the table 4, the parametric test results from the Independent T-test for the comparison analysis within the variables are shown. The values displayed in red are showing a clear significant differences between the points from layers 4 and 5.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Length	Equal variances assumed	.729	.397	-2.686	54	.010	-7.67619	2.85742	-13.40497	-1.94741
	Equal variances not assumed			-2.731	44.460	.009	-7.67619	2.81058	-13.33889	-2.01349
Width	Equal variances assumed	1.200	.278	-4.975	54	.000	-7.61905	1.53137	-10.68927	-4.54883
	Equal variances not assumed			-4.834	38.520	.000	-7.61905	1.57610	-10.80829	-4.42981
Thickness	Equal variances assumed	.174	.679	-3.204	54	.002	-2.40952	.75198	-3.91716	-.90189
	Equal variances not assumed			-3.263	44.698	.002	-2.40952	.73834	-3.89689	-.92216
Calculated volume	Equal variances assumed	.414	.523	-2.738	54	.008	-1.55284	.56706	-2.68973	-.41596
	Equal variances not assumed			-2.768	43.705	.008	-1.55284	.56092	-2.68352	-.42216

Table 4: Parametric test results from the Independent T-test. The values displayed in red are showing a clear significant differences between the points from layers 4 and 5.

Using the obtained outputs, the possibility of categorizing the similarities and differences within the points was investigated. Using clustering methods, regardless of the classification by layer, the most important variables (length, width, maximum thickness and volume) were clustered. The output clearly show the highest similarities and differences between each cluster represented in red color. Based on our initial trial on the data, the best clustering technique that could provide a solid and stable clustering, is the K-Means clustering method that we used here (Table 5). In addition, the overall clustering results also suggests that they are reliable and acceptable clustering (Figure 2).

K means Clustering	Layer
4	4
4	4
4	4
4	4
4	4
4	4
5	4
4	4
4	4
4	4
4	4
4	4
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4	5
5	5
5	5
5	5
5	5
4	5
5	5

Table 5: Results of the K-Means clustering. Highest similarities and differences between each cluster represented in red color

In Table 5, the first column indicates the clustering results obtained, and the second column show the recorded layer within the stratigraphic sequence. Those shown in red, are the clustering conclusions which are in consistent with layers. To assess the conformity or consistency in both methods, the KAPPA shows that the indicators were 40%, which is determined based on the following figure (Figure 1).

Model Summary

Algorithm	TwoStep
Inputs	4
Clusters	2

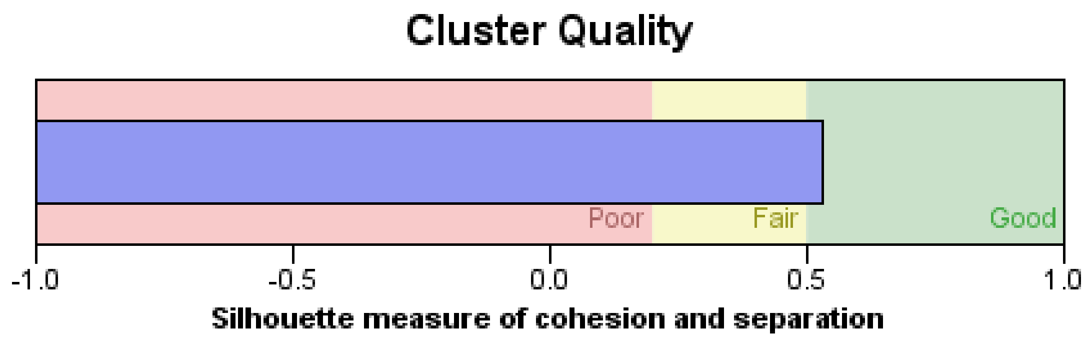

Figure 2: Overall clustering results

In the Figure 1, it is clear that, in the mid-axis of the plot, some points from both the layers mingled and mixed with each other. These are and the same points that are creating the heterogeneity with layering system within the stratigraphic sequence. Interestingly, these admixtures are those from the bottom of layer 4 and the upper most part of layer 5 respectively.

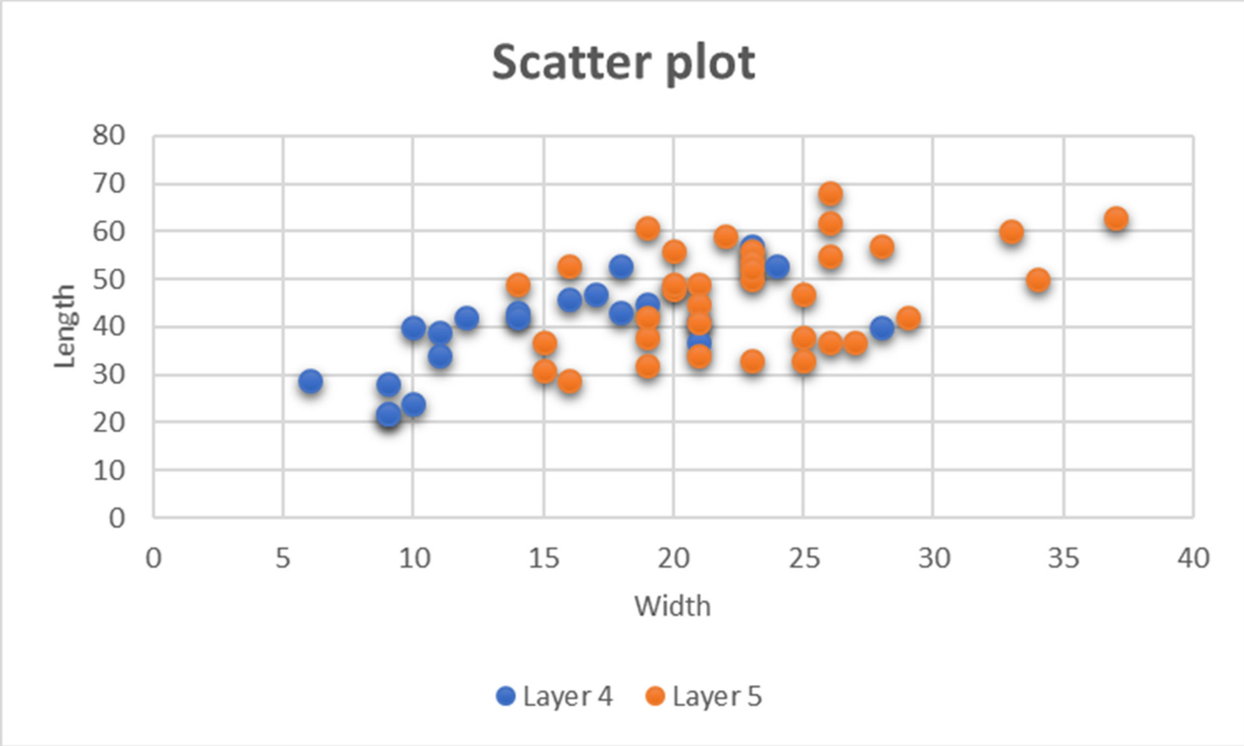

Figure 1: Plot showing the heterogeneity with layering system within the stratigraphic sequence.

Other interesting result in the obtained clusters that the software automatically generated, is that the tools in these two clusters are also showing significant differences within the variables such as length, width, maximum thickness and volume. Additionally it is also interesting that the resolution of the clustering results are much higher and efficient than the layers in stratigraphy. For more details, the significant amounts are shown in red in Table 6 (Table 6). However, it is worth mentioning that, the F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. Therefore, the observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal. We are just showing here the amount of the observed significant differences.

ANOVA

Layer		Cluster		Error		F	Sig.
		Mean Square	df	Mean Square	df		
4	Length	1292.595	1	35.703	19	36.204	.000
	Width	372.024	1	17.568	19	21.177	.000
	Thickness	44.024	1	4.801	19	9.170	.007
	Calculated volume	53.105	1	1.411	19	37.635	.000
5	Length	2630.002	1	35.936	33	73.186	.000
	Width	152.402	1	24.360	33	6.256	.018
	Thickness	50.060	1	6.530	33	7.666	.009
	Calculated volume	102.509	1	1.378	33	74.380	.000

Table 6: Observed significant differences from variables such as length, width, maximum thickness and volume. Significant amounts are shown in red.

Discussion and conclusion

Besides the quantified results performed on Kaldar lithic assemblage (Bazgir et al. 2017), in this study we attempt to provide the results of advanced statistical analysis with a higher resolution of the wider variabilities of indexes and values for a better assessment of the metrical differences within recovered points from layer 4 and 5 at Kaldar Cave. Here we attempt to overcome purely techno-typological analysis and tried to find out their correlation within the archaeological context and how these similarities and differences could be interpreted within the larger concept of transition from individual industries made by the Neanderthals and the *Homo sapiens*. The clustering method assumed us the normality and homogeneity of the selected variances. This provide a great opportunity to create a reference data for performing any comparative analysis on such assemblages that could furnish more accurate and detailed information than the pure techno-typological one. Our results in this study indicate a significant differences within the all measured values and shows some interesting similarities in the conjunction of two layers. Although more studies are needed to validate this results in a global agreement, however, based on our clustering analysis on the recovered points from Kaldar Cave, we propose a possible in situ evolution of the Baradostian from the local Mousterian in the Zagros Mountains.

Chapter 5: Discussion and conclusion

5-1: Discussion

From past several decades the transitional phenomenon from Middle to Upper Paleolithic has been a central debate and argument between researchers. Concerning Zagros Mountains, there have been some scattered researches, based mainly on lithic industries associated to the Neanderthals and Anatomically Modern Humans in this region. In this regard, Shanidar Cave with its secure Neanderthal fossil associated with lithic industry played an important role as a comparable base for lithic remains from other localities lithic remains. This made it easier for the researchers to differenciate between Neanderthal made tools with those made by modern humans. In our recovered assemblages from Gilvaran, Ghamari and Kaldar caves as well as Gar Arjeneh rock shelter, we observed similar Mousterian technology in each of the excavated sites. Except for Gar Arjeneh with its problematic stratigraphy, we found the presence of both Middle and Upper Paleolithic assemblages in all the three caves (Bazgir et al. 2014). These finds are highly important because of lack of such evidences in previous investigations in the area by different Iranian and international researchers. For instance, the most important excavated sites in the Zagros region lacked either from absolute dating or absence of Middle Paleolithic remains (reference). Ghar-e-Khar and Warwasi contain Middle and Upper Paleolithic but non of them provided any dates. Yafteh , Kobeh and Ghar-e-Boof provide dates but with absence of Mousterian remains (references).

It has been almost more than two decades that based on close typological similarities between Zagros Upper Paleolithic lithic assemblages with those in Europe, researchers such as Olszewski, Dibble and Otte proposed Iranian Zagros as the probable source of laminar technology with an east-to-west diffusion into Europe and named it Zagros Aurignacian (Olszewski 1993, Olszewski & Dibble 1993 &1994, Olszewski 2001, Olszewski 2007b, Otte et al. 2007, Otte & Kozlowski 2009, Otte 2014).Furthermore, Conard and his team realized more diversities within the bladelet assemblages in southern part of Zagros and introduced a new name so called Rostamian, derived from the Dasht-e-Rostam region where they reported large number of Upper Paleolithic sites, out of which a well stratified Ghar-e-Boof showed an age slightly more than 40,000 years (Ghasidian et al. 2009, 2017; Conard et al. 2011,).

It seems that lack of research and specially excavations in the Zagros region with addition to its huge geographical expansion with more than 2,000 km long from northwest to southeast and up to several hundred kilometres wide from east to west, makes it difficult to assess a definite explanation in regards to evolutionary process from Middle to Upper Paleolithic. There are some indications of an *in situ* evolution of Baradostian technology from its local Mousterian underlying in Warwasi rock shelter (Tsanova 2013). Considering the coarsely excavated deposits in this site, makes it difficult to apply the results by Tsanova to other sites in the region.

Some claim an Early Ahmerian like industry for the recovered lithic industry from Yafteh Cave and argue that continuity from the Zagros Mousterian to the Zagros Aurignacian cannot be confirmed. They further support the gradual transition from the Middle to Upper Palaeolithic at Warwasi and keep Zagros region a potential candidate for the origin of the Aurignacian (Otte et al. 2011, Shidrang 2013).

Ghar-e-Khar is another site in the Zagros Mountains that showed both Middle and Upper Paleolithic remains. Despite the argument of an in situ evolution of the Baradostian industry from its local Mousterian which has been shown in a techno-typological studies by Shidrang and Biglari, same as Warwasi, this site also was excavated coarsely using arbitrary units of 10-30 cms, cast doubt wither these results could be reliable or not. It is not clear to us how they could trace the connections between the lithic remains in such deep stratigraphic categories within the excavated units. As a matter of fact, in most of the cases, cave stratigraphies are much more complex than open areas sequences. Sometimes even in 5cm units it is difficult to track the stratigraphy. Some may argue that identifying the main characteristic of tools using techno-typological analysis along with finding refitable remains can play more role than just putting more stress on their associated stratigraphy. However, dealing with such a precise issue, one cannot easily assess or judge an in situ evolution of two different industries, without being sure about assemblage position within their stratigraphic sequence.

Another example of presence of Middle and Upper Paleolithic comes from the famous Shanidar Cave. In this case, unfortunately all the attention has been paid to its rich Neanderthal remains dating between 35000 to 65000 years ago. After a quick look to literature, one can find several studies on different aspects of its human fossils (Owen 2010, Solecki et al. 2004, Trinkaus 1983, Py-Lieberman 2004, Cowgill et al. 2007, Stewart 1959, Stewart 1961, Trinkaus 1983, Churchill et al. 2009, Solecki 1975, Sommer 1999, Pettitt 2002), but the lithic assemblage of this important locality in respect to their association with its stratigraphic sequence still poorly understood.

Concerning the dated sites but without Middle Paleolithic cultural remains, Ghar-e-Boof and Yafteh Cave are the best known localities in the Zagros. Both the sites have been well excavated and stratified. However, same as Üçağizli in Turkey, these two sites offers a little to the discussion of the transition from Middle to Upper Paleolithic, simply because of absence of a Middle Paleolithic underlying their Early Upper Paleolithic sequences.
Referring to issues mentioned about each of the above sites, in such scenario, Kaldar Cave opened a new window towards transition from Middle to Upper Paleolithic. This site contains an outstanding Mouterian assemblage along with its well dated Upper Paleolithic sequence. Moreover, in our investigation in the Khorramabad Valley, Gilvaran and Ghamari caves show the same type of cultural remains in their stratigraphy. In my opinion it is a matter of time and more sampling attempts in field work in these caves to achieve their chronometric data. However, comparing to previous studies in the region, our new excavations in the Khorramabad sites turned to higher potential concerning information on transition from Middle to Upper Paleolithic as well as chronological issues for the Zagros Mountains.
The achived dates from Kaldar Cave showed that not only for the old dates from Khorramabad sites but for the entire Zagros region there is a serious need for re-evaluation of all the achived dates from the old excavations. For instance, in 1960´s , Hole and Flannery dated the Mousterian layer of Kunji cave showing 40,000 years old. Whereas the achieved dates from the Upper Paleolithic sequence of Kaldar reaches up to 54,000 years. Surprisingly these two caves are few kilometer away from each other in the same valley. Apart from Kaldar dates, Yafteh Upper Paleolithic sequence have been dated in detailed several times. Yafteh Cave shows an age up to 41,000 years old. In our recent research on Bayesian age modelling, chronometric dates in the Upper Paleolithic sequences from Kobeh, Kaldar, Ghar-e-Boof , Yafteh and Shanidar suggest an age between 45,100-40,350 (68.2% probability) cal BP. All these show that the earlier obtained dates are not reliable anymore.

Coming to the faunal discussion, the fossils from the four different sites, do not show important differences in composition: horses, a possible rhinoceros, different species of deer and bovids. Horse remains were found in the Kaldar and Givaran Caves. They are large and of the caballoid types. The living *Equus hemionus* and fossil *Equus hydruntinus* are relatively small species with gracile metapodials. The caballoid horses are of a different type, they tend to be larger, with robust metapodials and a particular moprhology in the teeth. The remains from Kaldar and Gilvaran are of this type. Some authors see caballoid horses as a single species, as two, or even as many species (Azzaroli, 1990; Forstén, 1988, 1999; Eisenmann, 1991). The domestic horse *Equus caballus* belongs to this group, as well as its wild ancestor *E. ferus* would apply, but it seems likely that there were more caballoid species. The Przewalski's horse *(E. przewalskii*) is from Mongolia, though it survives only or mainly in captivity and the tarpan (*E. ferus*) went extinct in historic times in Europe (Groves & Grubb, 2011). *Equus mosbachensis* and *E. germanicus* represent possibly one or two different lineages, which went extinct during the Late Pleistocene. It is not clear to which of these the horses from Kaldar and Gilvaran Cave may have belonged.

The possible rhinoceros is a rare occurrence from the Pleistocene of Iran, which is situated between the long term distributions of different types of rhinoceros. Today three species of rhinoceros live in South and South-East Asia: *Dicerorhinus sumatrensis* and *Rhinoceros sondaicus* in SE Asia, while *Rhinoceros unicornis* lives in India (Duff & Lawson, 2004; Groves & Grubb, 2011). *Dicerorhinus* has a long fossil record in East Asia and *Rhinoceros* in the Indian Subcontinent (Colbert, 1935; Xue & Zhang, 1991). These are closely related species. The genera *Stephanorhinus* and *Coelodonta* are also closely related and they and the giant rhinoceros *Elasmotherium* lived in Northern Eurasia, but went extinct before the end of the Pleistocene (Guérin, 1980; Van der Made, 2010; Van der Made & Grube, 2010). *Stephanorhinus* reached the Middle East and Northern Africa and *Coelodonta* is also cited from the Indian Subcontinent (Colbert, 1935; Geraads, 2010). For a long time, it was custom to place the species of *Stephanorhinus* in *Dicerorhinus*. A "*Dicerorhinus*" of unknown specific identity was found in Wezmeh Cave (Mashkour et al., 2008). An upper premolar from the Qalehjough area was assigned to *Stephanorhinus* cf. *kirchbergensis* (Hashemi et al., 2016). *Stephanorhinus hemitoechus* and *S. kirchbergensis* have been described from Azokh Cave, which is not very far away in Nagorno Karabach (Van der Made et al. 2016). The remain from Gilvaran is tentatively assigned to the Rhinocerotidae and is certainly too poor for a more precise identification.

Sus scrofa is present in the Kaldar, Gilvaran and Ghamari Cave as well as in the Wezmeh and Bisitun Caves (Mashkour et al., 2008; Trinkaus & Biglari, 2006). The species lives today in an extensive area from Europe and North Afric to eastern and southern Asia, which includes Iran, and in most of this area it is the only species of suid

(Duff & Lawson, 2004).

Capreolus sp. was found in the Kaldar and Gilvaran Caves and in the Ghar Arjeneh Rockshelter. Today the species *Capreolus capreolus* lives in an area extinding from Europe to south of the Caspian Sea, which includes northern Iran. The larger species *Capreolus pygargus* with larger antlers, lives in an area that extends from north of the Caucasus to the East as far as China (Duff & Lawson, 2004; Aulagnier et al., 2009). The small size of the living *C. capreolus* seems to be a relatively recent phenomenon (Van der Made et al., 2006; Van der Made et al., 2014). The material from Kaldar and Gilvaran Caves and Ghar Arjeneh is relatively large, but it is not clear to which of the living species it is more closely related. Otherwise, the fossil record of the genus from Iran seems to be very poor or absent. Evins (1982) assigned a few specimens from Jarmo and "Mousterian levels" of Shanidar Cave in Irak to *Capreolus capreolus*. The specimens seem to be small indeed. In West Eurasia, the specimens the Khorramabad Valley constitute possibly the southernmost record of *Capreolus*.

Cervus elaphus is certainly present in Kaldar Cave and probably in the Ghamari and Gilvaran Caves as well. The species lives in an area that extends from Europe and North Africa to far into northern Asia and includes Iran (Whitehead, 1993). The species has been described or cited from Iran (Trinkaus & Biglari, 2006; Mashkour et al., 2008), NE Irak (Evins, 1982) and Nagorno Karabach (Lioubine 2002; Rivals 2004; Van der Made et al. 2016).

Bovini indet. are present in the Kaldar, Ghamari and Gilvaran Caves. The Bovini *Bos*, *Bison* and *Bubalus* all lived during the Middle to Late Pleistocene in Europe and the Indian Subcontinent. Fossil *Bos primigenius* and *Bos* sp. were been cited from Iran (Mashkour et al, 2008; Trikaus & Biglari, 2006). The auerochs *B. primigenius* was tentatively cited from Shanidar (Irak) (Evins, 1982). *Bison* was described from Azokh Cave in Nagorno Karabach (Van der Made et al. 2016). However the remains from the Kaldar, Ghamari and Gilvaran Cave do not allow for an asignation to one or another genus.

Capra sp. cf. *Capra aegagrus* is present in Kaldar Cave and probably also in the Ghamari and Gilvaran Caves. *Capra aegagrus* lives in Iran, while various other species of this genus live in areas relatively nearby: *C. caucasica* and *C. cylindricornis* in the Caucasus and *C. falconeri* in Turkmenistan, Tadzhikistan, Afghanistan and Pakistan.

Fossils from Iran were assigned to *Capra aegagrus* or *Capra* sp. (Marean, 1998; Mashkour et al., 2008, 2009), *C. aegagrus* from Shanidar (Evins, 1982) and *C. aegagrus* and *C. caucasica* from the Caucasus (Lioubine 2002; Touchabramichvili 2003; Rivals 2004; Van der Made et al. in 2016). Detailed descriptions are rare and it is usually not stated which features are considered to be diagnostic. In general horn core morphology is indicative, but specific features in the dental and post-cranial morphology are not well known. The fossils from Kaldar, Gilvaran and Ghamari Caves probably belongs to *Capra aegagrus*, but more diagnostic material is needed to confirm this.

Since the faunal remains are not very abundant, nor very indicative, their taxonomic classification is imprecise. Therefore any stratigraphic or ecological inference is even more imprecise. Bearing this in mind, it should be noted that the fauna is consistent with an environment not unlike the present (away from the urbanized areas). The faunal affinities are Palaearctic and European (or western Eurasian) in particular. In the present, the area is situated on the southern limit of the Palaearctic biogeographic realm (Holt et al., 2013). The Zagros Mountains form a narrow southern extension of the Palaearctic. The large mammal fossils from the Khorramabad Valley indicates that this was also the case during the Pleistocene. In mid-latitude Europe, such a fauna would be considered to be of "interglacial aspect", but Iran might have been a glacial refugium for such a fauna. There is no indication for major faunal change between the uppermost level with Mousterian or equivalent industry and the lowermost level with Aurignacian or equivalent lithic industry.

In this discussion, the general aspects on the Middle and Upper Palaeolithic (and especially the importance of the region for this debate) are quite well covered, but all the content regarding the specific contribution of your sites is mainly a repetition of what has been said in other sections.
The fauna section is quite detailed (apparently recycled from somewhere). But there is no mention to any specific aspect studied by you (the lithic study, the usewear analyses...).
I have the impression of having been reading the same ideas than in the introduction and in the papers, without going deep on your specific results.

5-2: Conclusion

As mentioned in the chapter 3 (3-3), Gar Arjeneh rock shelter did not show a clear stratigraphy which was the same problem for Hole and Flannary in their 1967 excavation. However, our new exacavations at Gilvaran, Ghamari and Kaldar Caves provided evidence for the replacement of the Mousterian industry by the Baradostian assemblages. Although Gilvaran and Ghamari yet to be dated, however, the achieved dates from the Upper Paleolithic sequence from Kaldar Cave assume their importance for future excavations mainly focusing on sampling attempts. Gilvaran Cave with its enormous and vast archaeological deposit, deep stratigraphy as well as rich lithic diversity, and Ghamari with a long stratigraphic sequence yet to be explored, both showed high potential for further investigations. Our excavation at Gilvaran Cave made it clear that previous assessment by other researchers relying only on a surface collection produced biased and showed that the recent excavations in the Khorammabad Valley provide new data necessary to fully understand the chronology, lithic industry and several other factors required for reconstruction of past activities by hunters and gatherers in this region. Our excavations led to recognition of two distinct but continuous layers from all the caves investigated in this thesis. The cultural remains from possible Neanderthals-made and *Homo sapiens* within the fill of these caves are of vital importance, because they provide data for understanding some of the dark angles of the possible interaction between *Homo sapiens* and the Neanderthals and the causes of the extinction of the latter.

In our excavations, apart from adding two more Middle Paleolithic sites (Gilvaran and Kaldar) in the list of Iranian sites, we were able to re-evaluate the fill of Ghamari Cave and Gar Arjenh rock shelter. This simply shows the need for more field works and research in the Khorramabad Valley.

Our techno-typological analysis of the lithic assemblages on all the excavated sites (except for Gar Arjeneh with stratigraphic problems) indicate that in the Mousterian layers there is the exclusive use of the Levallois recurrent unidirectional methods with the shift to the centripetal modality at the end of the flaking sequence. This is an issue which was strongly in disagreement with the claims by Hole and Flannery that there is absence of Levallois technique in the Zagros highlands (see also the assessmnets by Vahdati Nasab, 2010 and Roustaei, 2010). Our analysis show the agreement with Baumler and Speth, in a sense that the dimension of the raw material plays an important role in the choice of the knapping method, as is the case in small discoid cores. Our observations show the same results from techno-typological studies on Kunji Cave assemblage by Baumler and Speth that the notable scarcity of cores, the absence of refittable pieces, the large differences between the size of the tools and the size of the cores and their negative scars, and the condition of the cores that are exhausted, the chaîne opératoire is incomplete. Therefore, many of the artefacts were likely carried in from elsewhere (Baumler and Speth 1993). A clear shift from flake production to blade and bladelet technology can be seen within the Middle to Upper Paleolithic sequences in Gilvaran, Ghamari and Kadar caves. A significant difference between all the measurable elements within the Middle and Upper Palaeolithic layers. The technological analysis on all our recovered assemblages from Khorramabad sites indicate a homogeneity in differences between all the compared elements. These homogenities are in direction to greater weight and size of the items in the Mousterian assemblage compared to those of the Upper Palaeolithic assemblage. We believe that such fundamental similarities could provide a reliable foundation for interpretation and understanding the two industries, applicable not only to the Khorramabad sites but also it could be an important standardization at least for the rest of sites in the Central Zagros.

Within the recovered lithic assemblages from both seasons in Kaldar Cave presence of high percentage of points and pointed elements in both Mousterian and Baradostian sequences is a crucial factor. This abundance may indicate that the site functioned as an important hunting camp in the Zagros Mountains during both the Middle and Upper Palaeolithic times. This hypothesis appears to be supported by the zooarchaeological evidence in Bazgir et al. 2017, as well as preliminary use-wear results on some analysed pieces.

Concerning the dating issue, in addition to the presence of an outstanding Mousterian industry in the > 0.5-m-thick in layer 5 of Kaldar sequence, and despite the need for more chronometric data, the obtained dates from the lower part of the Upper Palaeolithic sequence in Kaldar Cave are some of the earlier dates attributed to a lithic industry produced by AMHs in western Asia. Our new obtained dates are of vital importance because they opened a new window towards understanding the emergenece of the Homo-Sapiens and the timing for the extinction of the Neanderthals not only in the Zagros region but also for the western Asia. Although this argument is not an intention to challenge the Levantine dispersal theory, but it supports the previous works noting that the Aurignacian may not have originated in only one area (see Douka et al. 2013 &Groucutt et al. 2015). Douka and colleagues suggest that the ages of Initial Upper Palaeolithic layers at Ksar Akil may represent that the transition from the Middle to Upper Palaeolithic in this area (and possibly in the wider northern Levant) occurred later than previously estimated. This finding would cast doubt on the assumed singular role of the region as an origin for human dispersal into Europe.

Radiocarbon dates from Kaldar Cave suggest that the transition from Middle to Upper Paleolithic may have happened prior to 49,200 ± 1800 BP, probably during the relatively warm MIS3. In this scenario, the faunal evidence does not support a coincident climatic change. Although more chronometric is needed to confirm its Mousterian sequence, however, the available data provides a highly interesting information in this part of the world concerning the replacement of Neanderthals by *Homo sapiens* without any indication of significant climatic change. These evidences show that the anatomically modern humans lived in Kaldar, are among the oldest groups who were capable of exploiting the Palaearctic fauna and were thus well adapted to this new environment, which they colonized shortly after the period of time recorded in the cave.

However, with such age, presence of modern humans in this part of the world is one of the oldest examples that show how these populations coped with the Palearctic climatic and environmental situations, which were new to them.

For this end, our excavations in Khorramabad Valley provided a great opportunity for a long term archaeological project with concentration on the high potential of the region regarding the Middle to Upper Palaeolithic transition/continuity. Indeed, we intend to continue our research using accurate information and maximum control of the context of the new excavations that includes careful sampling for chronometric dating from well-stratified sites and detailed techno-typological analysis. With a built team that consist several highly professionals in different areas of Paleolithic studies we will continue to benefit their expertise for understanding more the behavioural dimension of the transitional phenomenon by applying multidisciplinary studies.

5-3: Research perspectives

As mentioned in the introduction, after going through literature and the outputs of each team who did research in the Zagros region, one of the most important lessons I got from their experiences was that, the only successful projects are those leaded by the locals that produced continuations and published results. With this in my mind, since 2009, when I started officially my PhD, I had been always trying to identify research problems and un-answered questions from earlier works and did my best to find solutions for each them, consulting with different experts in this field from several universities and institutes across the globe. This opportunity was given to me by Institut Català de Paleoecologia Humana i Evolució Social (IPHES), mainly by Dr. Andreu Olle for accepting me as his PhD student and further supports by him that have been already explained in the acknowledgment. As a start point, I have been fully engaged with learning doing research in several aspects of Paleolithic studies benefiting from researchers and professors in IPHES. Moreover, having the opportunities to participate several times in the excavations at Sierra de Atapuerca provided me a great opportunity to be involved in one of the most important archaeological team in the world that made me learn how a proper project runs in a professional and global scale. Putting together these two privileges, made me think for establishment of a project in the study area where I have started my research. Working in this direction, in this thesis by benefiting from several experienced researchers (mentioned as co-authors in the presented published articles in this thesis), we succeeded to answer some of the un-resolved issues from previous works and added new interesting data for the continuation of research in the Zagros region. Moreover, as a matter of fact, new results from our excavation at Kaldar Cave strengthens Iran´s position in the world Paleolithic archaeology. In another word, data from Kaldar opened a new window in understanding more about emergence of modern humans and the disappearance of Neanderthals in western Asia, and as a fact, it put Iran in the world map as a large and important geographical region that had always acted as a corridor linking Africa to the Levant, Europe and Asia.

In continuation of this research, there are several more aspects that need improvements. In this regard we aim to carry out a detailed geological survey of the area, mainly to understand the correlations between the terraces with the archaeological deposits in the caves and shelters. Petromineralogy of the raw materials for comparison with the archaeological materials is another required information for a better assessment of the raw material sources, material preferences of the hunter and gatherer societies in the region, as well as looking for areas with more archaeological potentials through geological information. Another problem in the study area that need to be resolved, is the problem with finding other dating methods rather than only Carbon 14 which has its own limitations for older chronologies. In this sense, we already tried OSL and AMS dating on faunal remains that provided negative results. The density of the Middle Paleolithic deposits in the region seems to be the main problem for this method. Normally softer archaeological deposits are more suitable for OSL dating. Regarding AMS dating on faunal remains, we tried two times in different laboratories (Max Planck institute and Oxford laboratories). In both the cases we received negative results only due to lack of enough collagen preserved within the bones. It is therefore, in our future perspective in this project we will look for other dating opportunities like Paleomagnetism to overcome this problem and to obtain the age of the Mousterian assemblages in the region.

In regards to continuation of our multidisciplinary studies, we managed to organize two PhD opportunities devoted only on functional analysis and micro faunal studies of the Khorramabad sites. The mentioned PhD opportunities consist candidates Laxmi Tumung and Ivan Rey Rodríguez, dealing with functional aspects of the recovered lithic assemblages from Gilvaran, Ghamari and Kaldar caves and the micro faunal remains from Kaldar Cave respectively. By excavating Kaldar Cave in a larger area and future excavations at other localities we aim to provide more materials for increasing our future collaborators.

As a wide-viewing research, another important goal for the future perspective of our project will be devoted in finding sites with older chronologies in the region (specifically sites with Lower Paleolithic remais). Having this in mind since the beginning of this research, increasing evidence of Lower Paleolithic occurrences in neighbouring countries, as well as potential of the Zagros as a geographical crossroads between Africa, Asia, and Europe, made us think to look for such sites in central Zagros. As a preliminary result, in a new surface finding, we succeeded to report a locality with a clear Lower Paleolithic lithic industry. This site is located in the extreme border of Lorestan and Illam provinces. To provide a detailed information about the site and its lithic assemblage, our published paper entitled: “The Lower Paleolithic of Iran: Probing New Finds from Mar Gwergalan Cave (Holeylan, Central Zagros)” is presented in chapter 5, sub-chapter 5-4 at the end of this thesis. We aim to continue our search for finding more sites with such chronology, more preferably within Khorramabad zone.

Referring to above introduction, consequently, the interesting results presented in this thesis along with presence of hundreds of un-explored caves and rock shelters with high archaeological potential in the region, made me think of expanding our research in the area in a larger scale. In this direction, one of the most important goals within the future perspective of this research is to create a scientific infrastructure with a global standard. In this regard I already put forward initial steps towards public awareness by doing several interviews with different local news agencies in national and province levels. This provided the attention mainly of the Lorestan authorities and bringing the opportunity to raise a considerable financial aid by the government to stablish a human evolution museum in the Khorramabad city. The principal idea for a possible establishment of a museum is to train local young archaeologists for the future studies in a long-term perspective and to increase the scientific collaboration with international teams to improve the Paleolithic studies in the region. As a matter of fact, compare to nearby regions like Levantine, Iran in general and Khorramabad Valley in specific with all the mentioned potential is poorly known in a global context. We hope that by creating the mentioned infrastructures this research project could paved the way to overcome many of the obstacles mentioned in this thesis.

5-4: Publication 4

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PALEOENVIRONMENT. THE STONE AGE

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THE LOWER PALEOLITHIC OF IRAN: PROBING NEW FINDS FROM MAR GWERGALAN CAVE (HOLEYLAN, CENTRAL ZAGROS)*

The last half of the 20th century has been marked by spectacular new discoveries about the earliest colonization of Western Asia. In lands surrounding Iran, increasing evidence of Lower Paleolithic occurrences highlights this country as a geographical crossroads between Africa, Asia, and Europe. New effort recently accorded to this research has yielded probing surface finds from the Mar Gwergalan Cave in Holeylan. This paper provides a detailed description of the artifacts, and discusses them within a larger context of other Lower Paleolithic occurrences—both in Iran and in Western Asia, to ascertain the potential of this area for future research.

Keywords: *Lower Paleolithic, stone tools, Mar Gwergalan Cave, Central Zagros, Iran.*

Introduction

More than half a century has passed since Lower Paleolithic industries were first discovered in Iran (Braidwood, 1960; Braidwood et al., 1960). Still, only sparse finds attributed to this stage of early human stone-tool manufacture have been reported. With the exception of the Darband Cave site in Northern Iran, Lower Paleolithic occurrences are exclusively documented in open-air contexts (Biglari et al., 2007). Moreover, none of the Lower Paleolithic findings from Iran comes from systematically excavated sites nor from well-defined stratigraphical units. As a result, interpretation of the situation and timing of the Lower Paleolithic in Iran is presently limited to a few, isolated

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finds of artifacts recovered out of context. In most cases, no real distinction has been made between the two major techno-complexes that compose the Lower Paleolithic; that is to say, the Oldowan and the Acheulean. Up to now, the attribution "Lower Paleolithic" has been rather loosely applied in the literature to artifacts believed to precede temporally the onset of Mousterian-type toolkits. This is hardly surprising given, on the one hand, the non-standardized nature of Oldowan industries and, on the other, the fact that some Acheulean morpho-types may be present in Mousterian toolkits (denticulates, handaxes). It appears therefore to be of paramount importance to clarify issues regarding the timing and distribution of Oldowan and/or Acheulean producing hominins in Iran, especially with respect to the geographical situation of this country: at a crossroads between Africa, Asia and Western Europe.

The Khorramabad Valley, Kermanshah Plain and Holeylan region of Western Iran (Central Zagros) has long been a key area for studies related to the Paleolithic of Western Asia. The area has numerous caves, rock-shelters, and open-air sites whose archaeological potential has been reported by different authors exploring the region from the latter part of the 20th century. The Holeylan region is characterized by a vast plain surrounded by limestone mountains and crisscrossed by rivers and perennial springs. Its present-day configuration is probably quite similar to what it was during the Lower Paleolithic, when the vastly unexplored karstic systems must have provided an ideal shelter for early human groups crossing through or settling in the region. The Holeylan would also been attractive to early humans because lithic resources were readily available in local alluvials that were fed into by flint outcrops in the mountain ranges surrounding the plain. In the heart of the region, only around 2 km to the north-west of Kahreh, the Mar Gwergalan Cave constitutes a promising setting for future research (Fig. 1). Although in our recent visit (concerning the smugglers' pits), the sedimentary deposit in front of the cave has a thickness more than 2 m, a drawing of the western section of a sounding at the entrance to the cave shows a sedimentary infill of about 2 m (Mortensen, 1993). During the first excavations in 1974, some stone industries recovered from sequential levels in a small test pit were documented as belonging to Upper Paleolithic and Epi-Paleolithic cultural complexes (Ibid.). In 2012, new explorations resulted in the surface collection of a series of artifacts showing clear Middle

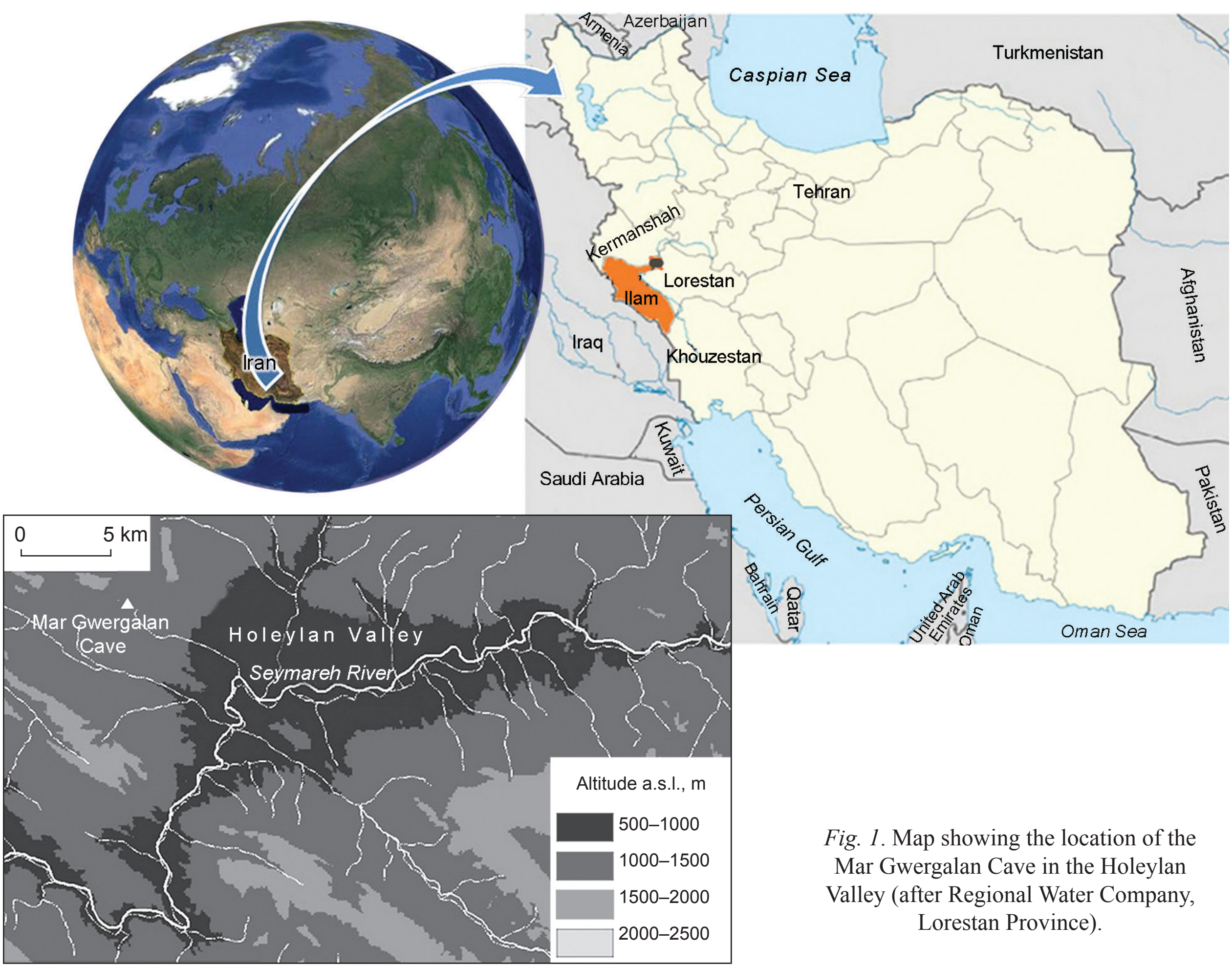

Fig. 1. Map showing the location of the Mar Gwergalan Cave in the Holeylan Valley (after Regional Water Company, Lorestan Province).

Paleolithic features, such as Levallois by-products, from: "…a different surface collection that was not reported earlier" (Davoudi et al., in press). This sample was also found to contain chopper-cores whose features are consistent with other assemblages documented in the Zagros Mountains and attributed to the late Lower Paleolithic (Biglari, Abdi, 1999). Techno-typological evaluations obtained from these surface finds have therefore significantly enlarged the supposed chronologies for a human presence at this site, suggesting that it could have been frequented from at least the Middle Paleolithic. In 2013, new explorations at the site (Davoudi and Bazgir) led to surface discovery of more lithic artifacts that (we propose) show possible affinities to Acheulean tool types. The aim of this paper is to present these new artifacts from the Mar Gwergalan Cave site, and to discuss their significance within the larger framework of early human expansions into Western Asia.

Geomorphology of the Holeylan region and the context of the Mar Gwergalan Cave

The Holeylan region in Western Iran (Ilam Province, Central Zagros) shares its borders with Lorestan and Kermanshah (Fig. 1). The region is characterized by both plain (so-called Holeylan) and mountainous landscapes (surrounding mountains: Qellasem, Dwemronah, Hwilon, Marāw, Zākhah, Kweranbezan, Owlaqouā, and Kwia Hwilah). The Seymareh River traverses the plain from the southeast to the northwest, dividing it into two parts. The upper part of Seymareh or Holeylan is in the Ilam Province, and the lower part belongs to Lorestan, which is a part of the Darb Gonbad rural area. The Jizman River flows from the center of the Holeylan plain in a north-south direction. This river environment also contains numerous perennial springs, notably in the western part of the plain where important water sources provide a rich biotype for humans, animals, and plants. Although there is to date no detailed study concerning the geomorphological situation of the Holeylan, some information about the tectonic formations and their composition has been made available, thanks to an unpublished GIS Map made by the Lorestan Regional Water Company (Fig. 2). The Holeylan Plain has been infilled by colluvials from the surrounding mountains, and also by the Seymareh and Jizman rivers alluvials. The plain, oriented northwest-southeast, thus comprises deposits from a variety of geological formations, including: Āmiran, Āsmari- Shahbāzān, Kashkān, Gurpi, Taleh Zang, Gachsārān, and Imām Hasan. A small fault running parallel to the Seymareh River within the

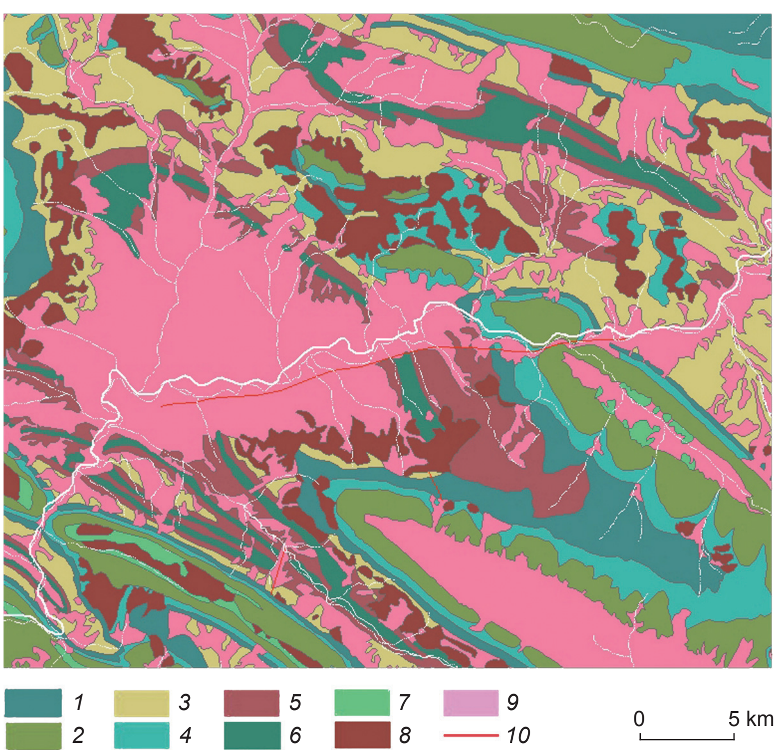

Fig. 2. Map showing the geological formations of Holeylan Valley (after Regional Water Company, Lorestan Province).
1–7 – formations: *1* – Taleh Zang, *2* – Asmari-Shahbazan, *3* – Amiran, *4* – Kashkan, *5* – Gourpi, *6* – Emam-Hasan, *7* – Gachsaran; *8* – landslips; *9* – alluviums; *10* – fault.

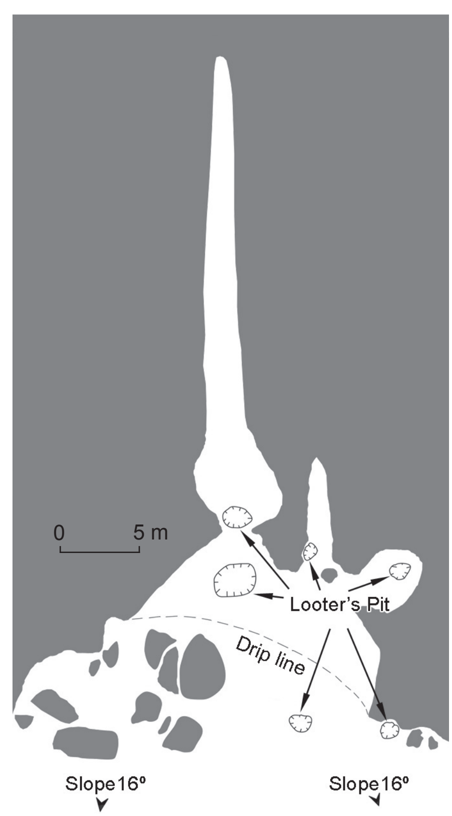

Fig. 3. Plan of the cave (after (Davoudi et al., in press)).

Fig. 4. Lithics.
1 – large bifacially knapped piece with a denticulate edge; *2* – cortical triangular pick in brown chert (shows a plano-convex profile and its lateral edges conserve the negatives of 7 removals); *3* – bifacial chopper-core in streaky brown chert (11 removal negatives); *4* – cortical massive scraper on brown chert (burnt, the striking platform is flat); *5* – core on a streaky cream-brownish colored chert pebble (displays several semi-peripheral, deep, bifacial removals).

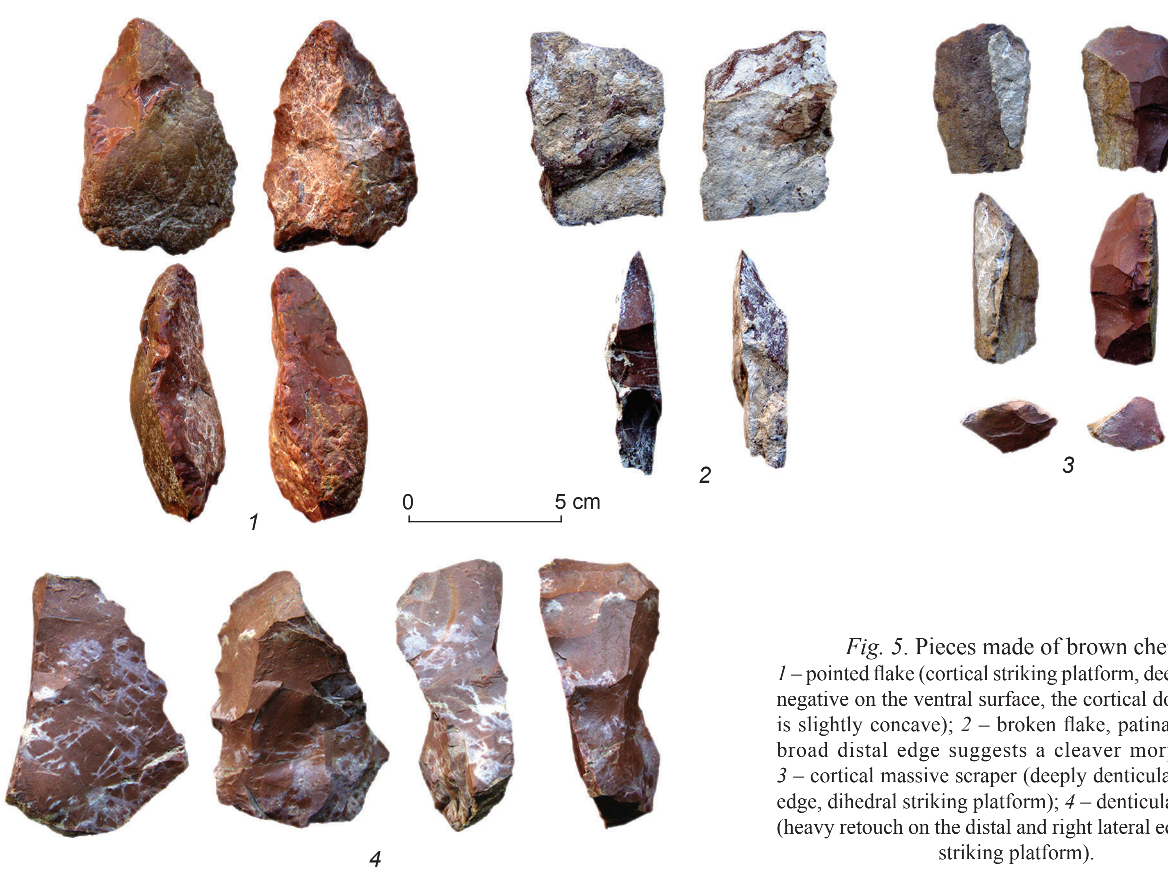

Fig. 5. Pieces made of brown chert.
1 – pointed flake (cortical striking platform, deep removal negative on the ventral surface, the cortical dorsal plane is slightly concave); *2* – broken flake, patinated (acute broad distal edge suggests a cleaver morphology); *3* – cortical massive scraper (deeply denticulated lateral edge, dihedral striking platform); *4* – denticulate scraper (heavy retouch on the distal and right lateral edges, thick striking platform).

boundaries of Lorestan near the Holeylan Plain likely attests to tectonic activity in the region.

The aforementioned formations are composed of marly shales, sandstones and cherty conglomerates (Casciello et al., 2009; Hakimi et al., 2010; James, Wynd, 1965; Parvin, Ahmadi, Manochehri, 2013), dating from the Paleocene, Cretaceous, and Quaternary (Homke et al., 2010). Throughout the Paleolithic, the Āmiran and Kashkān formations likely played an important role in providing the chert raw materials widely utilized for making stone tools. Abundant chert pebbles and cobbles originating from the erosion of the Āmiran and Kashkān formations, accumulated at the base of the plain, provided a significant source of raw materials for Paleolithic humans occupying the area. As in the Zagros, the numerous caves and rock-shelters carved into the mountains surrounding the Holeylan Plain vary in size, shape, and frequency according to the petrographic characteristics of the rocks in which they were formed (Heydari, 2007). Amongst these, the Mar Gwergalan Cave is carved into the limestone mountain of Gwergalan, at elevation of 1145 m ASL (Fig. 3). The mouth of the cave reaches up to 17 m wide and is oriented towards a south-westerly direction. With a maximum depth of around 40 m, the cave contains two main chambers connected by a narrow passageway (~2 m wide).

New discoveries of lithics from the Mar Gwergalan Cave

As a part of a renewed research initiative undertaken in 2013, we returned to explore the Mar Gwergalan Cave in order to ascertain its potential (Davoudi, in progress). During our visit, a total of 22 lithic artifacts was recovered from different surface locations around the cave (near the cave entrance, from the slope in front of the cave, and from the lowermost part of the slope) (Fig. 4, 5; Table 1). These new materials confirm the potential of Mar Gwergalan Cave as a key site to understanding successive human occupations from the Lower (Acheulean) through to the Middle (Mousterian), Upper Paleolithic and Epi-Paleolithic. Pending the re-opening of excavations at the site, the age of these different occurrences has yet to be determined. However, newly reported chronologies from Central Asia and the Levant suggest an age of around 250 ka BP

Table 1. **Artifacts recovered from Mar Gwergalan Cave (2013 field exploration)***

Type	Size, cm	Proposed cultural attribution*
Flake	5.2 × 3.9 × 1.5	Middle Paleolithic
»	5.0 × 4.0 × 1.6	
»	4.8 × 3.2 × 1.5	
Cortical flake	3.9 × 2.9 × 2.2	
Levallois flake	6.6 × 3.3 × 1.2	
»	4.1 × 3.6 × 1.2	
»	4.0 × 3.6 × 0.8	
Flake-core	5.8 × 4.0 × 3.2	
»	4.7 × 4.0 × 2.0	
Core	4.1 × 4.1 × 2.4	
Broken core	4.3 × 3.2 × 2.0	
Scraper	4.1 × 3.6 × 1.0	
End scraper	3.5 × 2.2 × 0.6	
Broken flake	7.0 × 4.1 × 1.2	Lower Paleolithic
Core on a pebble	6.7 × 5.8 × 4.8	
Large bifacially knapped piece with a denticulate edge	8.5 × 5.2 × 3.9	
Pointed flake	7.1 × 5.1 × 2.8	
Bifacial chopper-core	5.0 × 4.8 × 4.4	
Cortical triangular pick	11.3 × 8.7 × 6.5	
Cortical massive scraper	6.2 × 3.2 × 2.4	
»	7.3 × 5.5 × 3.0	
Cortical massive end-scraper	4.7 × 2.9 × 1.9	

*Proposed cultural attribution for the Middle Paleolithic artifacts is based on comparative morphologies from other sites in Khorramabad Valley (Bazgir, 2013; Bazgir et al., 2014).

for the end of the Lower Paleolithic or for the beginning of the Early-Middle Paleolithic (Mercier, Valladas, 1994; 2003). Also, a radiometric date of 148 000±35 000 BP was obtained from a bone fragment found in layer 2 of the Humian 1 rock shelter (Kuhdasht, Central Zagros) along with Zagros-type Mousterian industries (Bewley, 1984: 38). In contrast with the proposed timing for the Lower Paleolithic in the region (Mortensen, 1993), this finding confirms a Middle Paleolithic occupation during this timeframe. Even though some Lower Paleolithic tool types may be represented in Middle Paleolithic assemblages, further radiometric dating will be necessary in order to ascertain correctly the chronologies for these two techno-complexes in Iran. Keeping in mind all these problems, we emphasize that there will be no reliable dating until systematic excavations and new laboratory analyses have been approved. The following artifacts recently discovered at Mar Gwergalan Cave could buttress the dataset presently available for the Acheulean occupation of the Holeylan region (Ibid.).

The Lower Paleolithic in Iran and surrounding countries: a brief synthesis

Paleolithic research in Iran has been ongoing since the first stone artifacts were signaled in the 20th century; it has been plagued by geo-political difficulties linked to its long and complex history (Vahdati Nasab, 2011). In any case, the growing body of archaeological evidence coming out of the Levant, Turkey, and the Caucasus; all suggest that Western Asia in general, and certainly also Iran in particular, were strongholds for the appearance and evolution of all of the different phases of early human culture. In spite of the sporadic nature of Paleolithic research in Iran, a relatively large number of occurrences belonging to Middle, Upper and Epi-Paleolithic have been listed up to now, some of which have contributed to or been at the root of important synthetic theories about early human cultural evolution (Hole, Flannery, 1967; Otte et al., 2007; Dibble, 1984). However, evidence relating to the Lower Paleolithic (Oldowan or Acheulean) remains relatively elusive on the whole (Table 2). This observation may be partially explained by the specific historical aspects that guided research in Iran. Following the relatively numerous discoveries made during the 1960–1970s, these foreign research initiatives were put to a halt by the Iranian Revolution (1978–2000). Paleolithic fieldwork and surveying were also impeded for a twenty year period after the onset of the Iraq-Iran War in 1980. During this period, such research was largely carried out by Iranians whose "…educational background which was based on the later Prehistory and especially historic archaeology

Table 2. **Lower Paleolithic occurrences documented in Iran**

Location in Iran	Site name and/or location	Reference
Southwest, West and Northwest	Gakiah, 14 km E of Kermanshah	(Braidwood, 1960; Braidwood, Howe, Negahban, 1960)
	An area 46 km SE of Tabriz	(Singer, Wymer, 1978)
	Pall Barik, Holeylan, Central Zagros	(Mortensen, 1993)
	East Azerbaijan	(Sadek-Kooros, 1976)
	Cham-e Souran, Islamabad Plain	(Biglari, Abdi, 1999)
	Amar Merdeg, Mehran Plain	(Biglari, Nokandeh, Heydari, 2000)
	9 open-air sites, Mehran Plain	(Darabi et al., 2012)
	Khaleseh, Abhar Rud basin, Zanjan Province	(Alibaigi, Niknami, Khosravi, 2010)
	Shiwatoo, Mahabad region	(Jaubert et al., 2004, 2006)
	Kuran-Buzan, Central Zagros	(Alibaigi, Niknami, Khosravi, 2011)
South and Southeast	XāŠ Valley; Kuh-e Panj AngoŠt	(Maruchek, 1976)
	Ladiz, Mashkid and Simish river terraces	(Hume, 1976)
	Minab region	(Thibault, 1977)
	The terraces of the Kargar and Karoun rivers	(Ibid.)
	Baba Guri in Fars Province	(Conard, Ghasidian 2011)
North and Northeast	Kashaf Roud basin, Khorasan	(Ariai, Thibault, 1975)
	Ganj Par, Western Alborz Mountains	(Biglari, Heydari, Shidrang, 2004; Biglari, Shidrang, 2009)
	Darband Cave	(Biglari et al., 2007)
Central	Geleh site, Karkas Mountains	(Biglari, 2004)

courses, the Iranian archaeologists had little interest and proper knowledge in Paleolithic archaeology" (Biglari, 2012).

Given its geographical situation, the Iranian Plateau defines a sort of carrefour separating Africa, Central and Eastern Asia, and Europe. As such, it is generally considered a probable migration route for early human populations now known to have been present in neighboring lands by at least 1.8 Ma BP (the Dmanisi site in Georgia, Caucasus (Gabunia, Vekua, Lordkipanidze et al., 2000; Gabunia, Lumley, Vekua, et al., 2002; Lumley et al., 2002), and also sites in Northwestern Pakistan (Dennell, Rendel, Hailwood, 1988)). Although chronological issues remain to be resolved, it appears likely that Iran's diversity of landscapes, abundant caves, and generous water reserves must have made it a privileged area for more or less permanent human settlements from the Lower Paleolithic onwards. Rather than a barrier, the Zagros Mountains and their intercalated valleys and plains could have provided a resource-rich landscape for tool-making hominins in search of shelter and food. Indeed, evidence that hominins were capable of occupying high elevations is now attested at a number of early occurrences (Roustaei, 2010). In the Holeylan region, hominins could have found refuge in the generous caves available in surrounding mountains, descending into the plains during harsher climatic periods.

The first evidence of Lower Paleolithic industries in Western Iran was reported from Gakiah, a hill situated some 14 km east of Kermanshah (Braidwood, 1960; Braidwood, Howe, Negahban, 1960). The finds included numerous flakes, cores, and a single, standardized Acheulean handaxe. Subsequently, in 1970, a team led by R. Singer conducted surveys in the north-west of Iran in search of "pre-Moustrian" sites that would finally provide a link between the rich Lower Paleolithic discoveries of the northern Mediterranean basin (especially the Levant and Europe) and the Acheulean industries found in nearby Armenia, Azerbaijan, and Iraqi Kurdistan (Klein 1966; Braidwood, Howe, 1960). However, the only finds reported from this mission included a single handaxe from an area located 46 km south-east of Tabriz and a few other artifacts of dubious chrono-cultural attribution (Singer, Wymer, 1978). In addition, further discoveries of Acheulean lithics have been reported from the open-air site of Pall Barik in the Holeylan region after explorations by Mortensen in 1974. An age of 80–100 ka BP was proposed for these artifacts, on the basis of both geomorphological studies and techno-typological affinities (Mortensen, 1993). Further surveying was carried out in 1975 by H. Sadek-Kooros who explored the area between Tabriz, Marāgheh and Miāneh in the East Azerbaijan, in Northwestern Iran. There, three caves and seven open-air sites yielding artifacts attributed to the Acheulean were reported (Sadek-Kooros, 1976). The finds included side and end choppers, unifacially retouched flakes (scrapers), and some bifacially flaked cores.

More recently, during the first season of exploration at Cham-e Souran in Islamabad Plain, a small collection of artifacts showing late Lower Paleolithic features (including a small-sized chopper-core) was reported by an Iranian team (Biglari, Abdi, 1999). Some tools attributed to the Lower Paleolithic were also found at Amar Merdeg, in Southwestern Iran (Biglari, Nokandeh, Heydari, 2000). The finds come from nine sites in the Mehran Plain close to the Amar Merdeg site (Darabi et al., 2012). The Abhar Rud basin in the Zanjan Province of Northwestern Iran was more recently explored by S. Alibaigi (2003). His surveys exposed some artifacts showing Acheulean features, including: single- and double-edged choppers, chopper-cores, core-flakes, flakes, hammerstones, a heavy-duty scraper, and a cleaver-like piece from the Khaleseh site (Alibaigi et al., 2011). In 2004, S. Alipour and the members of Iranian-French joint mission studied the Lower Paleolithic assemblage from Shiwatoo, near Qaziabad in the Mahabad region (Northwestern Iran). Their techno-typological analysis indicated the presence of choppers, cores, bipolar on anvil flaking waste, evidence for large flake production, and pebble tools. The most significant find was a typical Acheulean cleaver made on a side-struck flake (Jaubert et al., 2006). In fact, many other sites with similar industries are reported from Mahabad (Jaubert et al., 2004). Finally, in 2010, a survey conducted in the Kuran Buzan region of Central Zagros led to the discovery of no less than 110 open-air sites, among which three are believed to have yielded lithics displaying Acheulean features (Alibaigi et al., 2011).

In Southeastern Iran, Lower Paleolithic sites have been revealed in the XāŠ Valley and on the eastern slope of Kuh-e Panj AngoŠt (Maruchek, 1976). The lithics from these occurrences appear to bear some resemblance to the Ladizian chopper-chopping tool tradition (Ibid.). There have also been reports of more sites with Acheulean lithics, notably from the Ladiz, Mashkid and Simish river terraces (Hume, 1976). In addition, an Iranian-French joint mission cited evidence for Lower Paleolithic industries in the Minab region of Southeastern Iran, and on the highest terraces of the Kargar and Karoun rivers of Southern Iran (Thibault, 1977). The latest report of Lower Paleolithic occurrence in this region comes from Baba Guri, an open-air site in Fars Province (Conard, Ghasidian, 2011).

The only information available for the Lower Paleolithic in Northeastern Iran so far is from the Kashaf Roud basin in Khorasan, where an Acheulean assemblage containing chopping-tools and other tool types was found in an open-air context (Ariai, Thibault, 1975). Somewhat later, in 2002, Acheulean industries were reported at Ganj Par, in the western Alborz Mountains (Biglari, Heydari, Shidrang, 2004). The assemblage comprises chopper-cores, cores, scrapers, bifacial tools (handaxes, cleavers, and a pick), large flakes, and hammerstones (Biglari, Shidrang, 2009). Around 16 km to the southeast of Ganj Par, the Darband cave site has since yielded the first evidence of a Lower Paleolithic occupation in Iran (Biglari et al., 2007). In 2003, Lower Paleolithic industries were found at the Geleh site, situated along the western edge of the central Iranian desert, about 10 km NW of Kashan, on the eastern slopes of Karkas Mountains (Biglari, 2004).

In addition to these Lower Paleolithic occurrences of Iran, we may also consider the growing body of data available from surrounding countries which have a bearing upon the hypothesis of an early arrival for both Oldowan and Acheulean producing hominins (early Middle Pleistocene). While evidence for the Oldowan is sparse, a few excavated open-air sites have yielded significant lithic samples from a reliable stratigraphic context. The most noteworthy testimony supporting an early human presence in Western Asia is, of course, from Dmanisi, a prominent Oldowan site located in the Georgian Caucasus. Dmanisi has provided rich archaeological evidence with hominin fossils in association with Oldowan tools and faunal remains dated to 1.81 Ma BP (Gabunia, Vekua, Lordkipanidze, et al., 2000; Gabunia, Lumley, Vekua, et al., 2002; Vekua et al., 2002; Lumley et al., 2002). The hominin remains present an array of anatomical features linking them to African hominins (*H. habilis*, *H. rudolfensis*) and others that evoke Asian *H. erectus* (Rosas, Bermúdez de Castro, 1998; Gabunia, Lumley, Vekua, et al., 2002; Dennell, 2009). Another excavated Oldowan site from this area that has yielded a few stone tools and faunal remains is Akhalkalaki (0.98–0.78 Ma BP (Tappen et al., 2002)). The next oldest human fossil find is a partial skull from a travertine sequence at Denizli in Turkey, recently dated to between 1.3–1.1 Ma BP (Lebatard et al., 2014). The so-called "Kocabaş hominid" displays features comparable to those of Chinese and African *Homo* fossils and is attributed to a form of *H. erectus s.l.* With Dmanisi, this is the only Lower Paleolithic occurrence to have yielded hominin remains. Still in Turkey, another core-flake industry has been signaled at the site of Dursunlu (0.99–0.78 Ma BP (Güleç, Howell, White, 1999).

Apart from this indubitable evidence for the first inhabitants of Western Asia, there are reports of Oldowan cultural remains from the stratified loess sequence of Kul'dara, in Southern Tajikistan (Davis, Ranov, 1999). The age of the cultural level containing core-flake industries without handaxes is evaluated at around 0.8 Ma BP by paleomagnetic correlation. There are no fauna at this site.

Inexorably linked to Iran as a migratory route leading from Africa into Western Asia is, of course, the Levantine corridor. There, such sites as Ubeidiya and Bizat Ruhama attest to the presence of hominins from around 1.6–1.4 Ma BP (Tchernov, 1992; Bar-Yosef, Goren-Inbar, 1993; Martínez-Navarro, Belmaker, Bar-Yosef, 2009, 2012; Ronen, 2006; Zaidner, 2013). In spite of their geographical and chronological proximity, the industries from these two sites differ greatly, perhaps underlining complexity and adaptive diversity in earliest human cultures: at Ubeidiya, toolkits are attributed to Early Acheulean and Developed Oldowan, while the core-flake assemblage from Bizat Ruhama seems to express local adaptation to raw material constraints (Zaidner, 2013). In nearby Syria, Oldowan levels have recently been signaled from the imposing archaeological sequence of Hummal (El Kowm (Le Tensorer et al., 2011)). At this exceptional site, successive archaeological layers bear witness to changing human cultures from the Oldowan (>1 Ma BP), through different phases of Acheulean, Yabroudian, and Mousterian and all the way up to historic Holocene occupations. Oldowan artifacts have also been reported from Northwestern Pakistan (Siwalik region (Dennell, Rendell, Hailwood, 1988)), Iraqi Kurdistan (Braidwood, Howe, Negahban, 1960), and the Arabian Peninsula (Chauhan, 2009); but further exploration, supported by systematic excavations and research, is still required in order to enlarge the information available concerning these occurrences.

The picture is somewhat clearer for the emergence of the first Acheulean sites in the countries bordering Iran, because of the clear increase in the number and density of excavated localities. This is especially true in the Levant at Evron Quarry and Gesher Benot Ya'aqov (Ron et al., 2003; Goren-Inbar, 1998), in Jordan at Duaqara (Parenti et al., 1997), and in Syria at Latamne (Clark, 1967; Tchernov et al., 1994) from around 0.9–0.8 Ma BP. Following this period, a larger number of Acheulean sites is known from Levant, Palestine, Jordan, Syria (Bar-Yosef, Belmaker, 2011), and from around Western Asia in general (Doronichev, Golovanova, 2010): from the shores of Bosphorus in Southeastern Anatoly (Bostanci,1961) to Iraq at Barda Balka (Wright, Howe, 1951), in Arabia at Rub' al-Khali (Field, 1961), in the Southern Caucasus at Kudaro I and Azykh (Doronichev, 2008), and in Pakistan's Siwalik Mountains (Dennell, Rendell, Hailwood, 1988; Biagi, Mukhtaiar Kazi, Negrino, 1996).

To summarize, thanks to renewed research efforts, the evidence is growing that attests to the early Oldowan occupations in the countries bordering Iran. Furthermore, in these countries there is abundant confirmation of an early onset of Acheulean culture (Caucasus, Tajikistan, Levant, Syria, Turkey), as well as for its successful implantation (Evron Quarry, GBY) and the subsequent development of its variants (Hummal, Qesem, Karaïn, Azykh Cave) (Le Tensorer et al., 2011; Biagi, Mukhtaiar Kazi, Negrino, 1996). It therefore appears manifest that these two complex components of the Lower Paleolithic should come to be better known in Iran in the future.

Discussion

In the last quarter of a century, debates about hominin occupation of Eurasia during the late Early Pleistocene have been brought to the fore by new discoveries of Oldowan sites in Europe that suggest an age of at least 1.2 Ma BP for the first colonization (Carbonell et al., 1995; Rosas et al., 2001; Toro Moyano et al., 2010; Parfitt et al., 2010; Despriée et al., 2009; Crochet et al., 2009; Arzarello, Peretto, 2010). Meanwhile, first hominin presence in East Asia is proposed as early as about 2 Ma BP (Zhu et al., 2001; Boëda, Hou, 2011). The need to fill in the huge spatial and temporal gaps separating the oldest eastern and western hemisphere Lower Paleolithic cultural occurrences outside of Africa has also recently been considerably highlighted for the Acheulean, with discoveries at Attirampakkam in India dating to 1.7 Ma BP (Pappu et al., 2011). In Western Europe, the oldest Acheulean site is presently dated to around 0.7–0.6 Ma BP (Piperno, 1999; Lefèvre et al., 2010; Barsky, Lumley, 2010; Moncel et al., 2013); while looking eastwards into China, the oldest Acheulean seems to be of comparable age (~0.8 Ma BP (Hou et al., 2000)). Western Asia in general, and Iran in particular, therefore constitute a huge geographical void separating these evidences: a sort of "no man's land" awaiting exploration to fill out the gaps in the fossil and artifact record.

Today, Western Asia encompasses what was previously referred to as the Middle and the Near East. It is roughly delimited by a number of important bodies of salt water (the Gulf of Oman, the Gulf of Persia, the Red Sea, the Mediterranean Sea, the Black Sea, and the Caspian Sea). Although it does not include Africa, it encloses countries situated in the continuity of the East African Rift Valley (Levant, Palestine, Jordan). In the "Out of Africa" scenario, the Levantine corridor is often cited as the most likely route taken by migrating early *Homo* groups (Derricourt, 2005). In this case, migrations out of Africa are sometimes thought to have occurred as waves (also pulses or events), the first of which consisting of Oldowan producing hominins, given the data from Dmanisi. Although the chronology of this event remains unknown, it is likely to have taken place during one of the most humid interglacial periods of 2.4–1.9 Ma BP (Agustí, Lordkipanidze, 2011). Arrivals of Early Acheulean–Developed Oldowan producing hominins from Africa into the Levant have been proposed from around 1.6 to 1.4 Ma BP (Saragusti, Goren-Inbar, 2001), following evidence from Ubeidiya (Tchernov, 1992; Bar-Yosef, Goren-Inbar, 1993; Martínez-Navarro, Belmaker, Bar-Yosef, 2009, 2012; Bar-Yosef, Belmaker, 2011). However, the hypothesis of "replacement" of the Oldowan by the Acheulean is not unanimous among scholars, and some propose a regional model (continuity) for change from one major techno-complex to another (García, Martínez, Carbonell, 2011). In any case, reliable faunal and cultural evidence maintain the Levantine corridor as a key area for hominin and other mammals migrating through the area as early as the late Early Pleistocene. Whether first migrations occurred from Africa (Bar-Yosef, Belfer-Cohen, 2001) or from Asia (Dennell, Martinón-Torres, Bermúdez de Castro, 2011), or both, remains a heatedly debated topic that needs to be alimented by further empirical evidence. In any case, data from such key sites as Dmanisi point to Western Asia as a key transit area from the earliest periods of human presence outside of Africa.

The existence of inter-continental affinities between Africa and Western Asia is also supported by the proximity of the African and Arabian plates (Yemen, Saudi Arabia). The Bab-el-Mandeb Strait has been proposed as possible transit zone for hominins and other large mammals migrating from Africa during different periods of the Pleistocene; but solid evidence for such crossings remains to be defined in the archaeological record (Petraglia, 2003). Notwithstanding this, current research in the southwestern part of the Arabian peninsula suggests high potential for finding Oldowan and Acheulean sites in stratified contexts with possibilities for radiometric dating (Chauhan, 2009).

It will be necessary to determine, in future, whether new evidence from countries such as Yemen confirms a passageway from Africa to Arabia or settlements of hominin groups that had arrived via the Levantine corridor. Western Asia also encompasses the Caucasus region where, in Georgia, the oldest evidence for Oldowan producing hominins outside of Africa has been established by abundant finds at the Dmanisi site (1.8 Ma BP, Gabunia et al., 2000, 2002; Lumley et al., 2002). While these and other discoveries have spurred new research initiatives in the Caucasus since the last half of the twentieth century (Georgia, Azerbaijan, Armenia), spectacular new data have recently confirmed an age of at least 1.1 Ma BP for the only *H. erectus* find so far discovered in Turkey (Lebatard et al., 2014), thus further underlining the archaeological richness of this period still lying in wait in the lands between the Black and Caspian Seas. Regardless of these recent advances, Western Asia is also characterized by "developing" countries, wherein complex geo-political situations have slowed the progress of early Prehistorical research (Iraq, Iran, Kuwait). It should also be stressed that research efforts up to now have mainly focused upon the somewhat more recognizable and very richly represented Epi-Paleolithic, Neolithic, and Metal Age evidence.

In sum, Iran constitutes an intensely promising area whose geography and history have, up to now, shadowed our understanding of the arrival and cultural metamorphosis of the earliest human groups outside of Africa. Western Asia is regarded as a likely migration route for early human groups moving out of Africa and into Eurasia and also, perhaps subsequently, back and forth between Africa, Asia, and Europe, diachronically from the late Lower Pleistocene. This paper synthesizes the data available for the Lower Paleolithic of Iran, and proposes to enlarge the picture of earliest human occupations in this country by presenting some probing new finds from the Mar Gwergalan Cave site in Holeylan (Central Zagros). Further excavations and research at this site should, in future, reveal more about the earliest colonization of Iran and, by extension, the diffusion of early humans throughout Eurasia.

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